SOIL SURVEYS: A CRITICAL EVALUATION WITH EMPHASIS ON USE IN URBANIZING AREAS

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ABSTRACT

SOIL SURVEYS: A CRITICAL EVALUATION
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By

Dan F. Amos

Since the first primarily non-agricultural soil survey, the Soil Survey of Fairfax County, Virginia, was completed in 1955, the "urban" soil survey has aroused considerable interest. Conflicting opinions have arisen as to what constitutes an "urban" soil survey, how accurately it represents the soil landscape, and how it can be improved.

Selected soil survey reports from 1902 to 1968 were examined to determine the point of inception of the "urban" soil survey and the rules and directives under which it operates. The "urban" soil survey was not found to exist as a separate entity.

In Clinton County, Michigan (a part of the Tri-County soil survey of an urbanizing area) 12 major mapping units were analyzed by the point-intercept transect method to determine mapping unit homogeneity. These mapping units contained from 22% to 98% inclusions at the phase of series level.

Soil maps produced by several soil surveyors working on a representative quarter-section were evaluated for precision, and agreement among themselves and with older soil surveys. Mapping precision among contemporary soil surveyors was lower than anticipated, lower, in fact, than the 1941 soil survey when it is evaluated by the older mapping unit descriptions. Contemporary mapping patterns indicated considerable personal bias among soil surveyors.

Four quarter-section quadrants were mapped at different scales by the same soil surveyor to determine the effect of mapping scale on mapping precision. Only at the series level did increased mapping scale improve mapping precision.

Several soil surveyors described the same two soil profiles and participated with others in estimating the texture of 20 soil samples. This was a measure of the soil surveyors' ability to estimate soil physical parameters alone and in combination. In addition, the variation in the conceptual model of a soil series among three soil surveyors was determined by comparing the modal and extreme individuals of the Conover series which they had selected.

Considerable variation existed among soil surveyors in their descriptions of the same two profiles, in their ability to estimate the textural classes of soil samples, and in their concept of the range of a soil series.

Several important physical parameters of 5 Tri-County soil series covering a wide textural range were determined as indices of variation for mapping unit inclusions. These physical parameters varied enough to cause serious difficulty if strongly contrasting inclusions were used in the same manner as the named mapping-unit component.

Deficiencies in the contemporary soil survey were attributed to two causes: operational and individual. Improving mapping unit descriptions should help the former while an imaginative, continuing program of in-service training and the development of an esprit de corps would go a long way toward improving the latter.

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The wife and children of a professional graduate student understand better than most that with love many things are possible, but without love few things are worthwhile.

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I. INTRODUCTION

Soil classification is still a young discipline. Less than a hundred years have elapsed since Dokuchaev pioneered the study and classification of soils as natural bodies with unique characteristics (Joffe, 1949, p. 25). As the body of characterization data grew, definitions of soil series underwent progressive refinement. From an essentially qualitative and general description of a group of reasonably similar soil individuals has evolved a lengthy, semi-quantitative statement of definition, which attempts to restrict the range of the soil series to a precisely defined portion of the taxonomic spectrum (Ableiter, 1949, p. 184; Soil Survey Staff, 1960, pp. 15-17).

With the refinement of the taxonomic unit another problem has evolved - the definition of the unit as mapped in the field. At first soil surveyors were convinced the area they had delineated on their maps as Miami loam was actually Miami loam with minor inclusions (Soil Survey Staff, 1951, p. 277). Later, after refinement, re-examination, and additional study, it became apparent that the mapping units were quite variable with many more inclusions than previously suspected (Powell and Springer, 1965; Wilding, Jones, and Schafer, 1965). The problem of how to most accurately define soils on the landscape and represent them in the synthesized universe of the soil survey map and report became increasingly important. The solution, however, could not be obtained by passing off the problem with a simple statement of "you can't show everything," while continuing to ignore the magnitude of the error involved.

Perhaps one of the best criteria to evaluate a system of

classification is how well its areas of inaccuracy can be defined. So long as a system fails to provide the means by which its defects can be identified, its potential worth is severely limited (Smith, 1965, p. 24). Errors in a system of classification may arise from the faulty logic of its construction or the difficulties in applying it to a universe of individuals. No system of soil classification based on recognition and identification of natural soil entities can rise above its expression in field identification and delineation of the basic mapping units, which is the substance of the soil survey.

In this study an attempt is made to measure the magnitude of error in selected samples of the Tri-County (Ingham, Eaton, and Clinton Counties, Michigan) urban soil survey, specifically in Clinton and Ingham Counties. Likewise, an attempt is made to apportion the error between the classification system (or the operational classification system as modified by administrative exigencies) and the human limitations of the individuals making the survey.

In addition, some of the requirements of an urban soil survey are examined; some limitations of soil surveys in general are enumerated; several modern "urban" surveys are critically evaluated; and suggestions are made to aid, hopefully, in designing urban soil surveys for greater benefit to potential users.

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[illegible]

II. LITERATURE REVIEW

A. DETAIL AND SCALE

Problems of what to include and what to omit are as old as soil classification and soil survey themselves. In reality, they have existed since man first attempted to reproduce or preserve a part of the world around him (Stebbing, 1950, p. 439). Unless he attempted to preserve a portion of his environment full-scale, he was forced to be selective. Even if he chose full-scale reproduction, man the artist could never really be certain he had observed everything, much less whether he had the ability to reproduce accurately what he had observed (Sinsheimer, 1971, p. 21).

The problem of selectivity has plagued man in nearly every line of intellectual endeavor. The historian has the perpetual problem of how much or how little to tell (Sedillot, 1951, p. 9); the cartographer must decide what detail he can show on his charts (Greenhood, 1964, pp. 48-49 ; Raisz, 1962, p. 34); the scientist must carefully select his observations, hoping his choice of individuals will encompass the universe of his investigation (Moroney, 1965, p. 120). The purpose of scientific sampling is based on the desire to obtain sufficiently accurate knowledge of the universe at the lowest cost (Petersen and Calvin, 1965, p. 54). Statistical analysis was created and exists to insure that those few which represent the many are accurately chosen, and that observed behavior is valid rather than the result of operator bias or abnormal reaction (Moroney, 1965, pp. 121-135; Pearson and Bennett, 1942, pp. 322, 368).

Koestler (1964, p. 190) has observed that the prerequisite of originality lies in the ability of the human mind to forget, at the

proper moment, what it knows. Consider the hypothetical case of a man sitting on the beach, watching the tide come in. To remember or record each individual grain of sand and every wave that washes the beach would be a task of formidable magnitude. For a person with mind capable of this, the past would be as real as the present, and he would be overwhelmed by an endlessly increasing store of perceptions (Sinsheimer, 1971, p. 27).

To relieve itself of this awesome drudgery, the human mind has devised the concept of the composite sand grain and the composite wave. Once these concepts are firmly fixed, individual representatives can be experienced without commanding more than a minute fraction of the attention of the sensory mechanism. We tend to ignore the modal or average and notice only the exception. We awaken to perception only when a sand grain is particularly shiny or dark, when a wave is unusually small or large. This is an advantage - a protective mechanism. It leaves us free to respond to the immediate without being overwhelmed by it. It permits us to withdraw sufficiently from immediate reality to develop ideas, to generalize, and to plan (Sinsehimer, 1971, p. 26).

Any good classification system is predicated on the concept of change. As information occurs and the body of knowledge about the individual builds, the place of the individual within the system and the system itself must change (Stebbing, 1950, pp. 436-437). Therefore, what is classified as "A" today may be relegated to "B" tomorrow. Soil classification has a long history of changing concepts and refinement of criteria, with the ultimate splitting of classes and attendant proliferation of soil series (Jacks, 1954, proper moment, what it means. Consider the hypothetical case of a man sitting on the beach, watching the [illegible]. To [illegible] of record each individual grain of sand [illegible] that makes the beach would be a task of [illegible] proportions. For a person with [illegible] of [illegible] that would be as cruel as the present, [illegible]

p. 164, Simonson, 1952, p. 250). That which is done with professional excellence today may be unsuited for the needs of tomorrow. In soil survey reports published prior to 1930, the description of benchmark series such as Miami (Mann and Baldwin, 1914, pp. 19-21), Cecil (Smith and Martin, 1901, pp. 216-222), or Hagerstown (Carter and Lyman, 1904, pp. 25-31) are much more general and less restrictive than the modern description of the same series (National Cooperative Soil Survey 1967, Ibid. 1971, Ibid. 1971).

Ever increasing refinement of taxonomic units, although beneficial in studying characteristics and predicting behavior of the individual, is not without attendant problems. Extreme conceptual refinement produces a theoretical individual whose counterpart in nature is difficult to find, at least in areas large enough to map. This has been reflected in the change in percentage of inclusions permitted in the mapping unit by the Soil Survey Manual as compared to that allowed in more recent directives. The original maximum of 15% has been increased until greater than 50% of the mapping unit may be composed of entities other than the one for which the mapping unit is named (Soil Survey Staff, 1951, p. 277; Soil Survey Staff, 1967, p. 12).

Carrying this to what is, perhaps, a ridiculous extreme, one might envision instances in which pedons - the basic units of soil classification - were delineated on soil survey maps. Certainly a precedent exists for showing areas of 10 square meters or smaller. Rock outcrops of this size are usually indicated by symbols (Soil Survey Staff, 1951, p. 223) as are numerous other non-soil and soil conditions of sufficient contrast to the mapping unit to be worthy of

notation. In times past, symbols were used largely as indices to show the nature of the mapping unit. No experienced surveyor would delude himself into thinking he could possibly find or show all significant variations on a soil map (Bushnell, 1927, p. 159; Soil Survey Staff, 1951, p. 277). Yet this is precisely what is expected today when an urban soil specialist is asked to make a detailed soils map of a proposed residental development. For when the price of land exceeds $1000.00 per acre, no soil condition within that acre is insignificant.

B. HISTORICAL DEVELOPMENT OF SOIL CLASSIFICATION

As with other sciences, the progress in soil classification over the past century has been spectacular. In contrast, early efforts in soil classification were sporadic. The origins of soil classification probably are lost in pre-history although we might visualize our sub-human ancestors learning to recognize and classify soil areas which were hazardous, or good hunting places, or barren. Some early attempts were made to classify land, but they were the results of royal commissions and probably undertaken by husbandrymen rather than scientists. And it was with husbandrymen that knowledge of soil classification resided through that era of intellectual dormancy known as the Middle Ages.

Not until 1882, when the government of Czarist Russia commissioned V. V. Dokuchaev to survey the soils of Nizhni-Novgorod for the purpose of equitable tax assessment was modern soil classification and survey born (Simonson, 1962, p. 1028). Dokuchaev's treatment of soils as natural bodies resulting from the influence of specific factors of formation rather than random assemblages of regolith was

fresh and innovative. Because of the great land mass of Russia with its broad bands of uniform climate and vegetation, whose lines of demarcation nearly coincided with certain parallels, perhaps he overemphasized the importance of these two soil-forming factors. It does seem that early Russian efforts emphasized "soil zones" and "great soil groups" at the expense of the soil individual.

Just at the end of the nineteenth century the United States soil survey program made its own humble beginnings. With a small staff, a modest budget, and the lack of a clear concept as to the nature of the soil individual, these pioneers went to the field and tried to describe and map what they saw. An idea of the difficulties they encountered may be visualized when one considers that the first clearly recognized statement of the natural soil body concept was published by G. N. Coffey in 1912 (Simonson, 1962, p. 1028) (Before one tenders too much pity to soil classification of this era, he should recall that the discovery of clay minerals as distinct entities did not occur until the next decade). Prior to this time soil surveys were mainly soil association maps accompanied by brief statements of the morphology of the units and a little about the agriculture and natural resources of the survey area.

In 1928 C. F. Marbut (1929), while emphasizing that soil was a product of a number of genetic factors rather than purely geologic rubble, set forth a 7-category system of soil classification:

Category	Class	Criteria
VII	Kingdom	$CaCO_3$ accumulation in profile
VI	Order	Sesquioxide mobility
V	Sub-Order	Climatic environment (temperature)
IV	Great Soil Croup	Climatic environment (rainfall)

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Category	Class	Criteria
III	Family	State of profile development
II	Series	Nature of parent material
I	Type	Texture of surface layer

Marbut stressed the fact that this system was based on the characteristics of the soils rather than those factors which were supposed to have produced these characteristics. This might seem to contradict his criteria of differientation for Categories V and IV, but rather than the climatic variables themselves he was thinking of differences expressed within the soil profile which were caused by these variables. One has difficulty in reconciling Category II criteria with his emphasis on profile morphology, however.

C. EARLY UNITED STATES SOIL SURVEYS

In the first decade of the twentieth century soil surveys were made at a very rapid rate. Ground control was maintained by means of a plane table and triangulation, and the usual scale was 1 in. = 1 mile or 1:63,360 (Soil Survey Staff, 1914, pp. 31-47). At this scale a pencil eraser covers approximately 40 acres. It also covers the minimum area in which a legible symbol can be included. In practice it was rare to find a delineated area that small. Normally delineations or separations were a minimum of 100 acres in size, and it was common to find entire sections (640 acres) in one delineation. This was true in the humid Eastern United States where soil patterns are normally more complex than in the west.

Not only was the mapping broad and inclusive but the concept of the soil individual was broadly defined also. Early series came to include not just the range of characteristics observed near the

geographical location where they were first described, but many more characteristics and variations as well (Fippin, 1911, p. 81). Likewise, in the survey area itself, the actual delineated units - the mapping units - usually were conceded to contain areas of contrasting soils too small to separate, but no quantitative measure of their size or extent normally was included in the text of the soil survey report. An example of this may be found in the Soil Survey of Harford County, Maryland (Smith and Martin, 1901, pp. 211-237), as reported in the Field Operations of the Bureau of Soils. In this county, with an area of 418 square miles and lying in two geological provinces - the North Atlantic Piedmont and Coastal Plain - 12 soil types were recognized and mapped. Six of these were classified as residual and six as sedimentary.

The most extensive soil type, comprising 41% of the area of the county, was called Cecil loam. It was described as being well watered and well drained, occupying gently rolling to rather hilly upland, and derived from the weathering of granites, gneisses, phyllites, and schists of the Piedmont Plateau. Depth of weathering was said to vary from a few to 30 or more feet. The soil consisted of a brownish-yellow silty loam, 10-15 inches deep, underlain by a lighter-colored silty clay loam. Variations noted were:

> Both soil and subsoil may contain from 10 to 20% of moderate-sized pieces of quartz and rock fragments.... Occasionally, at the depth of 20-30 inches, it grades into highly decomposed granite or gneiss that still preserves the rock structure....
>
> Occasional stony areas were noticed that are not easily tilled, but are kept in forest,... A notably stony area, indicated on the soil map by symbol, occurs as a narrow stony ridge about one half mile wide and 6 miles long, extending in an east-west direction through the village of

> Rocks, in the northern part of Harford County.... It consists largely of quartzite and quartzose sandstone and other metamorphosed rocks. The soil is generally found in a shallow layer resting on a broken mass of the rock from which it is derived... On the top of the ridge and on its steeper sides large masses of rock 3 to 50 feet in diameter protrude several feet into the air....

The author noted that the narrow stony ridge might be suited for chestnuts and orchard fruits, and that the rock composing the ridge would make fairly good road material.

In the Harford County soil map one uninterrupted delineation of Cecil loam covers an area greater than 36 square miles in extent, including broad, gentle ridges, steep side-slopes, and significant alluvial flats bordering the larger permanent streams. One must assume it contains the normally associated areas of excessively, moderately-well, somewhat-poorly, and poorly drained soils. The eastern corner of this delineation is at a lower elevation than a contiguous delineation of Susquehanna gravel (which is a sedimentary soil mapped at elevations varying from 100 to 400 feet above sea level). Therefore, it would be safe to assume this part of the Cecil loam delineation contains many small areas of overlay material unrecognized or unidentified at that time.

The field operations report of the Bureau of Soils for 1902 contained the results of the Soil Survey of Mount Mitchell Area, North Carolina (Caine and Mangum, 1902, pp. 259-268). The survey area included approximately 500 square miles of Appalachian Plateau in western North Carolina, with elevations varying from 1350 to 6711 feet above sea level. Rocks of this area were granites, gneisses, schists, some diabases and diorites, and significant areas of calcite. A total of 5 soil types and one rock outcrop class

were mapped, 4 of the soil types being upland and the other alluvium.

Porters clay is the most extensive soil type and is encountered on 31% of the land area. It is a reddish clay loam, 6 to 10 inches thick, over a red clay subsoil which sometimes extends to a depth of several feet before disintegrated rock is reached. The only variation in morphology mentioned is an occasional large quantity of quartz scattered throughout the soil and subsoil. Single, continuous delineations of this unit greater than 10 square miles in extent are common.

Within the next few years soil survey technique became a little more sophisticated. In the Soil Survey of Madison County, New York (Carr, Griffen, and Lee, 1907), made during the summer of 1906, the authors recognized that the soils of the county had diverse origins:

> Some of them are the results of feeble glaciation, some of heavy glaciation, some of glacial wash, some of reworked and water-deposited material, some from the accumulations of organic matter, and still others are the residual products of rocks weathered in place.

Volusia silt loam, which is mapped over 33.3% of the county area, is considered to be one of the feebly glaciated soils. It consists of a yellow or light-brown, mellow silt loam about 9 inches thick, over a yellow or frequently gray, compact silt loam or silty clay. The gray color is usually found, when present, in the lower depths. Inclusions noted are:

> Both soil and subsoil contain a varying, but usually high, percentage of flat shale fragments of various sizes. There is also present in many places a small quantity of rounded glacial stones....
>
> The surface soil often nearly approaches a loam in texture, there being in some areas a higher content of fine and very fine sand.
>
> Local areas on steep slopes, where the shale rock outcrops or

comes near the surface, are shown by symbol as rough stony areas.

Some delineations of this unit extend over 9 or more square miles; however, some areas as small as 3 acres are delineated. In this county of 649 square miles, 18 soils are identified and mapped.

These three examples of early soil surveys contain within their reports a discussion of the area and its history, something about the climate and agriculture, a discussion of geology and landform, descriptions of the various soil units, and, in the Madison County, New York example, a discussion of drainage, and a summary. They also contain a few tables of soil analyses, a few photographs in the North Carolina report, and the soil map of each area. The scale of these maps was 1:62500 or nearly 1 inch = 1 mile. At this scale a pencil eraser would cover 4 football playing fields laid end to end.

According to Marbut (1928, p. 4) the break with the concept of soil as basically no more than geological debris came about 1912. For the next few years soil surveyors were groping in confusion to find a workable basis for soil relationships. This seems, to the author of the present dissertation, a condition which has afflicted soil surveyors all too often to this very day. To be sure, no specific statement concerning soil genesis is contained in the manual, Instructions to Field Parties (Soil Survey, 1914), published by the U.S.D.A., Bureau of Soils. About the closest this publication comes to a comment on the genesis of soil is:

> The identification of soil units or types in the area is based upon the general character of the soil and subsoil material, the general character of the topography and the physiographic situation, the source or derivation of the material, and the agencies through which the material has been accumulated (Soil Survey Staff, 1914, p. 67).

Rather definite instructions were given in this manual for identifying and mapping soils. Unless a base map had been previously prepared, the soil surveyor was expected to construct his own base map, to identify soil units, and to delineate soil boundaries. To identify soil units the surveyor was guided by the following characteristics:

> Color of soil and subsoil - to a depth of 3 feet in the humid region and 6 feet in the arid regions,...texture of the soil and of the subsoil,...structure of soil and of subsoil material;...drainage conditions of soil and subsoil, and any marked chemical or mineralized features.

In addition he was to note topographic and physiographic features such as valleys, mountains, plateaus, terraces, lake beds, and flood plains; sources of origin such as granite, basalt, phyllites, sandstones and shales, limestones, and mixed material; and process of accumulation such as residual, ice-laid, water-laid, and wind-laid.

The number of borings to examine the soil adequately was left to the discretion of the field man who was to be guided by the complexity of the soils of the area. Borings were expected to vary from "widely scattered" in an area of obviously uniform soil conditions to "very frequent" along boundary lines and in areas of very complex soil conditions. Clues which might indicate a change in soil conditions and warrant investigation were slight depressions or elevations, change in color of the surface material, or a change in the character of the vegetation. Even though the concept of soils as natural bodies was not yet recognized by the authors of this manual (their elements of classification consist of soil provinces, such as Glacial Lake & River Terrace Provinces, and soil series: and they admit the distinction between soil and subsoil had never been clearly defined), instructions for conducting a soil survey were comprehensive.

Although the 1914 manual lists 5 acres as the minimum size allowable for a delineation, in practice a much larger separation was the norm. This was understandable when one considers that a delineation 3/32 inch square would equal about 5 acres when the scale is 1 inch = 1 mile. Nevertheless, in the Soil Survey of Accomac and Northampton Counties, Virginia (Stevens, 1920), a number of delineations this size were made. In the Soil Survey of Pittsylvania County, Virginia (Kirk et al., 1922), a few of these minimal delineations are shown, but the average size is much larger, with some delineations of 1500 acres or more.

Soil survey reports in the second decade of the twentieth century continued in essentially the same format although discussions of soil genesis and morphology (Tharp and Artis, 1922, pp. 14-26) and use and management of individual soil types (Stevens, 1920, pp. 36-59) were considerably expanded. Typical descriptions of individual soil types may be found in the following reports: Soil Survey of Orange County, North Carolina (Vanatta, Brinkley, and Davidson, 1921, pp. 27-30)

Davidson clay loam

> ...to a depth of 6 to 12 inches consists of a dark-brown or reddish-brown to dull-red, heavy loam to clay loam, underlain by a dull red or maroon-red, smooth, friable clay....
> ....
> Basic rocks such as diorite, diabase, and hornblende schist.... at a depth of 15 to 20 feet....

[Inclusions]

> ...deeper, more loamy, and more brownish soil occurs in

been closely defined), instructions for conducting a poll [illegible] more comprehensive.

Although the [illegible] [illegible] [illegible] as the minimum size allowable for a delimitation, in practice a [illegible] larger [illegible] was the norm. This was [illegible] and the boundaries [illegible] the wooded areas,...over the cultivated fields,...the surface soil is shallower, heavier, and redder.... Along...narrower ridges...rock fragments, mostly of diorite,...

White Store fine sandy loam (Vanatta et al., 1921, pp. 43-45)

...light brownish gray to light-brown fine sandy loam extending to a depth of 6 to 10 inches.... The subsoil typically consists of a plastic, impervious clay, dull red in color mottled with gray.... The undecomposed parent-rock material, sandstone, mudstone, and shale, is nowhere more than a few feet from the surface,...

[Inclusions]

The surface 4 or 5 inches,...is commonly darker in color and more open in structure, owing to its greater organic content.... the subsoil colors...[range] from solid dull red through red mottled with gray, to gray mottled with red and yellow, or even dull-yellow...in...small galled spots ...the soil is a shallow, dull-red loam,...on long gentle slopes and in depressions the sandy covering may have a depth of 12 to 18 inches.... Along the shoulder of the stream slopes there is frequently a narrow strip of brownish-red fine sandy loam to loam underlain by an Indian-red, friable clay subsoil.... typical of the Penn series,...

Soil Survey of Wayne County, North Carolina (Derrick, Perkins, and McDowell, 1916, pp. 23-26)

Norfolk fine sandy loam

...6 inches...of a light-gray to gray fine sandy loam... a pale-yellow or yellowish-gray fine sandy loam...for about 12 to 15 inches.... The typical subsoil to a depth of 36 inches or more is a yellow, friable fine sandy clay.

[Inclusions]

In the vicinity of Sevensprings...[the subsoil] is encountered at depths varying from 18 to 28 inches. In the depressions the surface soil has a dark-gray color caused by the organic matter present, and the subsoil is sometimes mottled with gray. In the higher areas the lower part of the 3-foot section occasionally presents mottlings of red. Small areas of Norfolk sandy loam and very fine sandy loam and of Ruston fine sandy loam, too small to be separated, are mapped with this type.

Soil Survey of Accomac and Northampton Counties, Virginia (Stevens, 1920, pp. 36-40).

Sassafras sandy loam

...a light-brown to brown, mellow sandy loam, from 9 to 15 inches deep.... a reddish-yellow or reddish-brown heavy loam to a depth of from 30 to 36 inches, where it passes rather abruptly into a loamy sand of about the same color as the heavier layer above....

[Notes and inclusions]

[The upper layer has] a relatively even distribution of the coarse, medium, and fine grades of sand, with a relatively large proportion of silt, which gives a decided coherency to the soil mass.... The reddish-brown color of the subsoil is more pronounced in the more thoroughly drained portions.... West of Hallwood and Bloxom are small gravelly areas. Throughout the drainage divide of the peninsula, narrow ridge like areas are of frequent occurrence, and in these the subsoil layer is often thinner, the sandy substratum sometimes appearing within 2 feet of the surface. The depth of surface soil varies widely on these ridges,...[due to] erosion.... Many areas of this type have a subsurface layer...more compact...[of] yellowish brown.... probably...induced by cultivation...

Soil Survey of Johnson County, Iowa (Tharp and Artis, 1922, pp. 23-27).

Clinton silt loam

...light grayish brown or brown very friable silt loam,... [to] a depth of 8 to 10 inches.... yellowish-brown heavy silt loam to silty clay loam, friable to crumbly,...light yellowish brown or pale-yellowish silt loam,...easily penetrated with a soil auger,...to its contact with the underlying glacial material,...which is seldom less than 4 or 5 feet...

[Notes and inclusions]

Soil and subsoil are invariably acid to litmus paper, but the substratum at from 6 to 8 feet...is generally alkaline,... The organic matter content is low and usually confined to the first few inches.... Near the rivers there are occasional high points capped with sandy material. These areas resemble the Knox sand. In Jefferson and Big Grove Townships the areas near the Iowa River have in many places a sandy substratum.... areas east of Cedar River include many such textural and structural variations, due to admixture of wind-blown sand.

Soil Survey of Latah County, Idaho (Agee, Graves, and Mickelwaite, 1917, pp. 16-19).

Moscow loam

> 10 inches...[of] a yellowish-brown to light grayish-brown or light-brown loam, of somewhat silty texture and friable structure.... [2 to 4 feet] of a light-yellowish to grayish or yellowish-brown loam.... (usually granite, in places quartzite or schist)... within the 6-foot section....

[Notes and inclusions]

> [The surface soil] contains small quantities of quartz and mica.... where the parent rock has completely weathered [the subsoil] is often a stiff, plastic clay.... bright red [in some places, but usually]...grayish or yellowish brown.... The surface soil...is influenced in character by fine loessial or wind-laid material, and the gradation between the wind-laid soils and Moscow loam in places is so gradual that arbitrary boundaries of separation had to be drawn.... Outcrops of granite, quartzite, and mica schist are numerous.

D. EARLY SOIL SURVEYS OF LAND-GRANT COLLEGES

During this era two land-grant colleges were conducting soil surveys and publishing soil survey reports independently: The University of Illinois and Iowa State Agricultural and Mechanical College. The format of the Iowa State report was similar to those of the U.S.D.A., Bureau of Soils with sections on agricultural systems and soils; however, it did not contain a discussion of the climate of the area. It did include sections on geology, physiography and drainage, fertility status of the soils, results of greenhouse and plot work in soil fertility, methods of erosion control, and an excellent appendix explaining soils in general and soil survey methods. Soil type names were in general agreement with those used by the Bureau of Soils but the soil maps were published at a scale of 1 inch = 2 1/2 miles. This may have been a

calculated cartographic reduction to fit the map nicely into the survey report, but it gives the finished product a more detailed appearance than its contemporaries.

The format of the University of Illinois report was similar to that of Iowa State although the topics were slightly different. They contained sections on areal geology, physiography and drainage, soil material and soil types, fertility management and field experiments, a rather detailed discussion of individual soil types, and an appendix explaining soil survey methods and principles of plant nutrition. The soil map was published at a scale of 1 inch = 2 miles, but the amount of detail is about the same as others of this era - 3 continuous sections were observed to fall within a single delineation.

In Iowa, as in Illinois, many soils were formed in loess. The following illustrates how the individual soil types were described in these states at this time:

Soil Survey of Lee County, Iowa (Stevenson et al., 1918, pp. 27-28).

Grundy silt loam

12 to 14 inches...[of] a dark-brown to black silt loam.... [10 to 12 inches of a] dark-brown to black silty clay loam... a clay loam mottled with pale yellow, yellowish-brown and bluish-gray....

[Notes and inclusions]

In the deeper subsoil the material becomes heavier in texture and approaches a silty clay. In the level areas the subsoil is a dark-brown to bluish-gray in color with little yellow or yellowish-brown and a heavier texture.

In the soil report of Winnebago County, Illinois, the soils were given descriptive instead of series names. For example:

Brown silt loam (626 and 726) (Hopkins et al., 1916, pp. 34-36) ...0 to 6 2/3 inches,...[of] a brown silt loam...[4 to 10 inches of brown silt loam with a] slightly larger percentage

of clay and about one-half the percentage of organic matter [of the upper layer].... [20 inches or more of a] yellow to a drabbish yellow, slightly clayey silt,...

[Notes and inclusions]

It normally contains from 50 to 70 percent of the different grades of silt and from 10 to 15 percent of clay. It sometimes grades imperceptibly into a fine sandy loam,... [The encroachment of timber] gradually modifies the soil by lowering the organic-matter content,...[The surface color varies] from a brownish yellow on the more rolling areas to a dark brown or almost black on the more nearly level and poorly drained tracts.... [The sub-surface layer is] thinner on the more rolling areas and thicker on the level areas [The subsoil] contains a variable amount of sand.... [It is] drabbish colored...only in the lower, poorly drained areas.

This survey report and map was the product of the University of Illinois alone. No attempt was made to correlate the soil types with those being recognized and mapped by the U.S.D.A., Bureau of Soils. Undoubtedly, they were attempting to be as quantitative as the state of knowledge permitted; for this is apparent from the type description. Yet such an approach of necessity would curtail free interchange of information and ideas with others working with similar soils elsewhere.

To their credit they clearly recognized that the soil was a product of climax vegetation as well as geologic formation.

The appendix of this report contains, among other things, an explanation of soil survey methods, soil characteristics, and groups of soil types. As an indication of the status of the science at this time, these sections are included below.

Soil Survey Methods (Hopkins et al., 1916, pp. 63-65)

The detail soil survey of a county consists essentially of ascertaining, and indicating on a map, the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To

accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of the work; and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries must match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and corrected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining directions of angling roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, ditches, streams, and necessary corrections are placed in their proper locations upon the map while the mapper is in the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils for this purpose being carried in the field.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extention for making the auger 80 inches long is carried by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

Soil Characteristics

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical, or mechanical, composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) the agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

Soil constituents	Organic matter	comprising undecomposed and partially decayed vegetable or organic material	
	Inorganic matter	Clay	.001 mm and less
		Silt	.001 mm to .03 mm
		Sands	.03 mm to 1.0 mm
		Gravel	1.0 mm to 32.0 mm
		Stones	32.0 mm and over

Groups of Soil Types

The following give the different general groups of soils:

Peats - Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.
Peaty loams - 15 to 35 percent of organic matter mixed with much sand. Some silt and a little clay may be present.
Mucks - 15 to 35 percent of partly decomposed organic matter mixed with much clay and silt.
Clays - Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams - Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.
Silt loams - Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.
Loams - Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.
Sandy loams - Soils with from 50 to 75 percent of sand.
Fine sandy loams - Soils with from 50 to 75 percent of fine sand mixed with much silt and a little clay.
Sands - Soils with more than 75 percent of sand.
Gravelly loams - Soils with 25 to 50 percent of gravel with much sand and some silt.
Gravels - Soils with more than 50 percent of gravel and much sand.
Stony loams - Soils containing a considerable number of stones over one inch in diameter.
Rock outcrop - Usually ledges of rock having no direct agricultural value.

More or less organic matter is found in all the above groups.

In the section on soil survey methods the stated goal of the mapper keeping exactly located falls under the "impossible dream" category. An approximation of within 50 feet is good in open fields, and this may vary to several hundred feet in heavily wooded areas.

Under the heading of soil characteristics, the factors used in establishing soil types are comprehensive, although the method of using these factors is not explained. Emphasis is placed on organic matter and soil texture in this section as well as in the next section on groups of types.

E. COOPERATIVE SOIL SURVEYS: 1920-1950

Soil surveys of the Bureau of Soils continued into the 1920's with the same general format: descriptions of the area, climate, agriculture, and individual soil types, with a summary at the end. The following two survey reports are good examples:

Clay loams - Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.
Silt loams - Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.
Loams - Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.
Sandy loams - Soils with from 50 to 80 percent of sand.
Fine sandy loams - Soils with from 50 to 80 percent of fine sand mixed with much silt and a little clay.
Sands - Soils with more than 80 percent of sand.
Gravelly loams - Soils with 25 to 50 percent of gravel with much sand and some silt.
Gravels - Soils with more than 50 percent of gravel and much sand.

Soil Survey of Dallas County, Texas (Carter et al., 1924, pp. 1227-1229)

Houston black clay

...a very dark bluish gray to black clay, 12 or 15 inches deep.... a [grayish or] dark bluish gray or black clay,...

[Notes and inclusions]

In flat or slightly depressed areas...[subsoil color] is a dark bluish gray or black... On sloping areas the subsoil is in many places dark brown, grading through brown to yellowish brown with increasing depth. Where the type is underlain by chalk at depths of 3 to 5 feet, the lower subsoil may be yellow or greenish yellow and contain white, soft, chalky particles. Where the soil overlies marl and calcareous clay, the chalky material is not so abundant,... In some places the underlying chalk comes to within 2 feet of the surface. This type is locally called "black land" or "black wavy land".... In uncultivated fields large, deep cracks form in this soil in dry weather,... [In cultivated fields] it crumbles down, on drying, to a mass of small aggregates or crumbs.... In the large areas north of Mesquite and around New Hope there are included patches, 20 to 50 feet across, that contain whitish salts called "alkali spots".... Such areas represent inclusions of Wilson clay. Some quartz gravel occurs...in places,...[possibly] a remnant of old water-laid deposits.

This report is accompanied by a map at a scale of 1 inch = 1 mile, and the detail is rather broad. While as much as 16 contiguous sections lie in some mapping unit delineation of Houston black clay, in other sections 6 or more delineations may be found.

The Soil Survey Report of Orange County, Virginia (Hendrickson, 1927), was similar in format to that of Dallas County, Texas. Both reports include a section which briefly discusses the genesis and morphology of the soils of the survey area. Although this section is brief, it points out the generally acid nature of the soils and stresses the importance of parent material on the development of

soil profiles and their characteristic morphologic features such as texture, color, organic content, and permeability. Formation of soil profiles is explained as being a function of parent material, native vegetation, climate, imperfect drainage, destructive erosion, and age of the soil. Since this is a 1927 survey, there is little question that the ideas of C. F. Marbut were being strongly felt by the field workers.

The second most prevalent soil in Orange County, and one of the best known in the Eastern United States, is summarized below:

Davidson clay loam (Hendrickson, 1927, pp. 4-8)

> ...a 1 or 2 inch surface layer of deep-brown heavy loam or silt loam containing considerable organic matter,... [3 to 5 inches of] dark-brown or reddish-brown clay loam or heavy silt loam.... [26 to 33 inches of] deep-red or maroon-red clay of uniform texture.... [3 1/2 to 4 1/2 feet of] a smooth clay layer of slightly less intense red color, containing a few black streaks and ocherous-yellow spots and splotches.... [which] increase with depth...parent diorite or trap rock...

[Notes and inclusions]

> A thin covering of leaf mold and leaves lies on virgin Davidson clay loam,... In most places the surface soil contains sufficient sand to give it a mellow and fairly friable consistence.... In cultivated fields...[surface color] ranges from deep reddish-brown to red... The subsoil...has a smooth feel and breaks into angular particles from less than a quarter inch to a half inch in diameter. In some places a few soft small manganese oxide concretions are present.... [This] is a well-defined soil type, remarkably uniform in all its characteristics. Minor variations occur in rock content, depth of weathering, intensity of color, surface relief, and surface texture. More resistant masses or boulders of parent rock are seen in many places in road cuts in the weathered clay subsoil, and in a few places they outcrop.... The soil may be 8 or 10 feet deep [between the boulders mentioned previously].... [Along contacts with Montalto soils] the upper part of the soil fades into paler red,... A few small scattered areas of Davidson loam,...were included [in this unit].

Following the points mentioned above are an additional two pages of discussion of Davidson clay loam including: location and extent within the county; relief; drainage; infiltration; water-holding capacity; run-off and erosion; consistence and its influence on cultivation; native vegetation; land use; crop yields; crop suitability; management systems for high production; total elemental analysis of a Davidson clay loam profile; nutrient status of this soil in relation to soils of the Southeastern U. S., Northeastern U. S., and the Great Plains; a mechanical analysis of a profile; particle size distribution; and structure.

As an indication of the progress made in understanding and describing soils during the 1920's, compare the description of Davidson clay loam in the Soil Survey of Orange County, North Carolina (Vanatta, 1921, pp. 27-30), to the description of the same soil in the Soil Survey of Orange County, Virginia (Hendrickson, 1927, pp. 4-8). Apparently much progress had been made during this period.

Of the 22 soil series and 28 soil types mapped in the Orange County, Virginia, soil survey, all but about 6 of the minor types received a page or more of treatment by the author of the report. This survey is a continuation of the trend noticed in the Dallas County, Texas, report, a precursor of the more detailed reports to come.

The accompanying map is at the 1 inch = 1 mile scale, with as much as 4 square miles included within one mapping unit delineation. In other sections as many as 8 or more delineations per square mile may be found.

In tracing the early evolution of the United States soil survey, it might be well to consider an example from the West in the early 1930's. The format of the Soil Survey of the Tucson Area, Arizona (Youngs et al., 1931), is similar to the Soil Survey of Orange County, Virginia, except for the addition of a section on erosion, and one on irrigation, drainage, and "alkali".

This soil survey is unique among those considered to this point in that it consists of two parts mapped in differing degrees of detail. The southeastern part, consisting of about 80 square miles occupied by the Santa Rita Experimental Range, was surveyed under the administration of the United States Forest Service in greater detail and on a larger scale than the main part of the Tucson area. Because it is indicative of the effect larger scale and greater detail have on soil survey administrators, and the effect elimination of detail has on the published map, even until now, the following is quoted from this survey report:

> In reducing the scale (for economy in publication), certain details in mapping have been sacrificed, and minor discrepancies between the soil map and text of this report may occur (Youngs et al., 1931, p. 1).

Because of the importance of the Santa Rita Experimental Range, the description of the survey area in this report goes into much greater detail than normal in the treatment of native vegetation, giving both common and botanical names for the various species.

In the section on climate certain variations are called to the attention of the reader. At the University of Arizona the elevation is 2423 feet above sea level, mean annual temperature is 67.3^{o}F, and mean annual precipitation is 11.55 inches. In the range part of the survey area the elevation varies from 2900 to

5200 feet, with the climate becoming more temperate and humid as one ascends the mountains to the southeast. Just south of the experimental range, at an elevation of 5000 feet, the average annual rainfall is 19.74 inches.

The section in which general characteristics of the soils of the area are treated seems to be comprehensive and lucid. Soils of the valley are separated into two broad groups: older upland soils having definite accumulation of $CaCO_3$ (caliche) in the subsoil, and more recent alluvial soils lacking this layer. In the range area three broad groups are identified: (1) deep-brown, friable, sandy soils in recent alluvium, (2) old red and brown soils with tough, red subsoils, and (3) old gray, limy soils with more or less firmly cemented subsoils. In this section genetic factors affecting soil development are discussed in considerable detail. The dry, hot climate is responsible for the valley soils having a,

> small, but readily available, quantity of organic matter (humus and nitrogen), and a high content of the more soluble mineral compounds, including lime and magnesium carbonates and salts of sodium and potassium, commonly called 'alkali' (Youngs et al., 1931, pp. 11-12).

The normal red or pink tinge of the soils is attributed to the high degree of oxidation of their iron compounds. Older soils have been slightly leached of lime carbonate and other compounds which have accumulated in the subsoil, forming, in places, more or less cemented layers called "caliche" which signifies a lime hard-pan. At higher elevations the older soils have heavy, tough, red upper subsoil layers caused by the transfer of clay and colloidal material from the surface to subsurface layers.

5200 feet, with the climate becoming more temperate and humid as one ascends the mountains to the southeast. Just south of the experimental elevation of 2000 feet, the average annual

In the evaluation of distribution and growth of the different plant species on the Santa Rita Experimental Range, the authors of this report felt that while soil differences played an important role, they were secondary to the amount of moisture available for plant growth. Since available moisture is related not only to rainfall but also the soils' capacity for absorption and release of moisture, the soil remains a very important indirect influence. These observations undoubtedly led the authors to conclude,

> Apparently the physical characteristics of the soil are, as a rule, more important than its chemical composition in determining its adaptability to the growth of grass, although chemical differences seem to have a distinct correlation with the distribution of certain species of grasses and shrubs, and also influence their height and vigor of growth. Local soil differences apparently have much less effect in the more moist cooler upper belt than in the lower drier and hotter parts of the experimental range (Youngs et al., 1931, p. 13).

Erosion hazards are discussed in a separate section, the primary causes being steep slopes, high-intensity rainfall, proximity of land areas to drainage channels, lack of organic matter, and lack of protective vegetation which is often caused by overgrazing. One of the characteristics aiding some soils' resistance to erosion is the presence of "desert pavement" which is a nearly continuous, unbroken layer of surface gravel.

The section entitled "Irrigation, Drainage, and 'Alkali'" discusses the problems created by irrigation with water containing 16 to 200 parts of salts per 100,000. Occasional "flooding" is recommended to leach accumulated salts from the surface and deposit them in lower horizons. Salt distribution was evaluated using three levels of concentration: F - < 0.2% salts - "alkali free", S - 0.2 to 0.7% - slight to moderate concentrations of alkali salts, In the evaluation of distribution and growth of the different plant species on the Santa Rita Experimental Range, the authors of this report felt that while soil differences played an important role, they were secondary to the amount of moisture available for plant growth. Since available moisture is related not only to rainfall but also the soils' capacity for absorption and release of moisture, the soil retains a very important indirect influence.

and A - 0.7 to 3.0 + % - strongly alkaline which must receive special treatment before plant growth is possible. Sites at which tests were run for alkali concentration are indicated on the map by a fractional number such as $\frac{.2}{.3}$ which indicates .2% of salts at 1 foot and an average of .3% salts to a depth of 6 feet below the surface.

An example of soil type descriptions contained in this report is that of the second most extensive soil type within the survey area:

Pinal sandy loam (Youngs et al., 1931, pp. 39-40)

[A few inches to 3 feet of] light grayish-brown or pinkish-brown coarse sandy soil...[A few inches to 2 feet of softly to firmly cemented] light-gray or almost white lime hardpan, or caliche,... [3 feet to 6 + feet of] much softer slightly cemented coarse sandy or gravelly material,...

[Notes and inclusions]

[This soil] occupies the greater part of the mesa land... [in] Tucson...and large areas north, east, and south of the city.... [The landform is] smooth, gently rolling, or ridged...[and] constitutes the remnant of a very old terrace or alluvial fan now lying at a higher elevation than the surrounding land.... outcrops of hardpan occur in many places.... The texture [of the surface layer] ranges from gritty loam to coarse sandy loam, [and] in many places containing a rather large quantity of gravel and chunks of caliche.... The hardness of the caliche layers...[varies from] softly cemented...[to a] very hard capping layer... The surface soil is poor in organic matter, humus, and nitrogen, dries out quickly in most places, and is not of sufficient depth to allow adequate room for root development....

A number of small poultry ranches are located on it, and on these a few small plots of alfalfa or other greens are grown for poultry feed, and a few small family gardens are maintained.... where trees or shrubs are to be grown, holes are dug or blasted through the hardpan and these are filled with good soil hauled from the bottom lands... The good soil is also spread over the surface where lawns or gardens are to be grown. The native vegetation consists largely of creosote bush, together with a scattered growth of stunted mesquite.

Although soil type descriptions in this report lack the morphological detail and evaluation of inclusions which were becoming standard procedure in this era, they were good from the standpoint of use and management. The increasing attention to soil genetic factors other than nature of underlying geology undoubtedly was influenced by Marbut's translation of Glinka's Great Soil Groups of The World and Their Development (Glinka, 1927).

In the section entitled "Soils and Their Interpretation" two profiles are described in greater detail than in the section on "Soils and Crops". The description (called a "study") of one of these soils is given below:

White House gravelly sandy loam (Youngs et al., 1931, pp. 52-53).

A_1 0 to 1 1/2 inches, a loose layer of pale-red gravelly sandy loam, which has a slightly acid reaction (pH 6.5).
A_2 1 1/2 to 10 inches, dark reddish-brown or dark-brown friable granular sandy loam or loam, which apparently contains considerable organic matter. This layer is slightly acid.
B_1 10 to 28 inches, intensely dark red or maroon clay containing much gravel and stone. The material has a dense cloddy or irregular blocky structure, with vertical cracks or cleavage planes, through which dark organic matter and roots have penetrated. The material in this horizon, like that in those above, is slightly acid.
B_2 28 to 42 inches, brownish-red tough clay containing a large quantity of disintegrated rock. The material has a neutral reaction.
B_3 42 to 60 inches, a mass of disintegrating boulders (rhyolite, trachyte, granite, syenite, diorite and other rocks). through which have penetrated tongues of tough red clay. The material in this horizon gives a slightly alkaline reaction by the La Motte test, but it does not effervesce when treated with hydrochloric acid. At a depth of 60 inches there is a mass of boulders which cannot be dug through.

This soil profile was located on a high, smooth, moderately sloping alluvial fan near White House Station at an elevation of about 3,900 feet. This is, apparently, a very old undisturbed surface which lies about 50 feet above a large drainage channel

about one-fourth mile to the east.

The soil map of the Tucson Area, Arizona, is published at a 1 inch = 1 mile scale, and detail throughout the largest portion of the area ranges from one delineation of some 5 square miles to some sections with as many as 20 delineations per square mile. As indicated in the report, the Santa Rita Experimental Range is mapped in greater detail, which is evident even after alteration of the original field sheet delineations before publication. The average number of delineations seems to be about 15,with no section containing less than five or six.

In the latter part of the 1930's a noticeable lag between the completion of the actual field work of a soil survey and publication of the survey map and report becomes apparent. No doubt this was caused by limited publication funds toward the end of the Great Depression. This trend continued, and the discrepancy in time increased through the war years of the early 1940's. The trend is not good, for there are instances in which the useful life of a soil survey is greatly curtailed by publication lag. Whenever the lag is as much as a decade, technological advances may have rendered obsolete large portions of the published survey while it is still "hot off the press."

An example of a survey of the late 1930's and background for the present study is the Soil Survey of Clinton County, Michigan (Johnsgard et al., 1942). Again the format has changed slightly: the section on agriculture expanded to agricultural history and statistics, insertion of a section on soil survey methods and definitions, the soils section expanded to include soils and crops about one-fourth mile to the [illegible].

The soil map of the [illegible] area, [illegible], is published on a 1 inch = 1 mile scale, and [illegible] throughout the [illegible] [illegible] [illegible] delineation of [illegible] [illegible] (as was the case in the Tucson Area, Arizona, survey), sections added on productivity ratings, land use, and agricultural methods, and a section entitled "Morphology and Genesis of Soils."

As a statement on the status of the science and development of the operational policy in a Cooperative Federal-State soil survey (circa 1936), the following section is quoted in full:

> Soil Survey Methods and Definitions
>
> Soil surveying consists of examination, classification, and mapping of soils in the field.
>
> The soils are examined systematically in many locations. Test pits are dug, borings are made, and exposures, such as those in road or railroad cuts, are studied. Each excavation exposes a series of distinct soil layers, or horizons, called, collectively, the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is studied in detail; and the color, structures, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The reaction of the soil and its content of lime and salts are determined by simple tests. Drainage, both internal and external, and other external features, such as relief, or lay of the land, are taken into consideration, and the interrelation of soils and vegetation is studied.
>
> The soils are classified according to their characteristics, both internal and external, special emphasis being given to those features influencing the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics, soils are grouped into mapping units. The three principal ones are (1) series, (2) type, and (3) phase. In some places two or more of these principal units may be in such intimate or mixed pattern that they cannot be clearly shown separately on a soil map but must be mapped as (4) a complex.
>
> The most important group is the series, which includes soils having the same genetic horizons, similar in their important characteristics and arrangement in the soil profile, and developed from a particular type of parent material. Thus, the series includes soils having essentially the same color, structure, and other important internal characteristics and the same natural drainage conditions and range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The soil series are given names of places or geographic features near which they were first found. Thus, Miami, Hillsdale, and Coloma

(as was the case in the Tucson area, Arizona [illegible]), [illegible] added on [illegible] [illegible] [illegible] and a special [illegible] [illegible] [illegible].

[illegible]

are names of important soil series in Clinton County.

Within a soil series are one or more soil types, defined according to the texture of the upper part of the soil. Thus, the class name of the soil texture, such as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, and clay, is added to the series name to give the complete name of the soil type. For example, Miami loam and Miami silt loam are soil types within the Miami series. Except for the texture of the surface soil, these soil types have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the soil unit to which agronomic data are definitely related.

A phase of a soil type is a variation within the type, which differs from the type in some minor soil characteristic that may have practical significance. Differences in relief, stoniness, and the degree of accelerated erosion are frequently shown as phases. For example, within the normal range of relief for a soil type there may be areas that are adapted to the use of machinery and the growth of cultivated crops, and others that are not. Even though there may be no important difference in the soil itself or in its capability for the growth of native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated crops. In such an instance the more sloping parts of the soil type may be segregated on the map as a slope phase or a hilly phase. Similarly, soils having differences in stoniness may be mapped as phases, even though these differences are not reflected in the character of the soil or in the growth of native plants.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types, phases, complexes, and miscellaneous land types, in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

The weather data from the East Lansing station in Ingham County, just southeast of Clinton County, indicate a mean annual temperature of 46.8^{o}F, with mean annual precipitation of 31.43 inches and average total annual snow depth of 47.2 inches. The climate is described as somewhat insular because of the proximity to the Great Lakes. Winters are moderately cold, and summers are mild and pleasant with moderate precipitations and low wind

... are names of important soil series in Illinois ...

(b) Within a soil series are one or more soil types, defined according to the texture of the upper part of the soil. Thus, ... class name of the soil texture, such as sand, ... loam, silt loam, clay loam, clay ... added to the series name to give ... type. For example, ...

movement. Precipitation is almost uniformly distributed throughout the year, and the nature of the rainfall tends to be gentle.

Soils of Clinton County are described as differing greatly in texture, color, natural fertility, and chemical composition. This might seem strange since the major portion of the land surface consists of level to rolling glacial plains, except for the north-eastern corner which is an old lake-bed plain. However, there are numerous swampy depressions and small lakes, especially in the more rolling southeastern part; while old glacial valleys from 20 to 60 feet in depth and from a few hundred yards to 3 miles in width traverse the county in an east-west direction. The natural drainage system is only weakly developed since the land surface is relatively young, and the relatively subdued relief of 670 to 900 feet, which averages only about 220 feet above the level of Lake Michigan, is not conducive to rapid dissection. As a result of this, numerous areas of wet land occur both as depressions and as level plains.

Intermediate soil textures are dominant with loams occupying about 60%, soils heavier than loam about 20%, and sandy loams and sands about 11% of the total area. Organic soils make up about 8% of the county while lakes and streams account for less than 1% of the area.

Undisturbed, well-drained soils possess the following horizons: (1) dark gray or dark grayish-brown surface high in organic matter and generally less than 3 inches thick; (2) a light brownish-yellow or light yellowish-gray horizon low in organic matter and clay; (3) yellowish-brown or reddish-brown more or less sticky and compact material higher in clay than any other part of the soil profile. The

combined thickness of these three horizons usually ranges from 3 to 4 feet over unconsolidated materials which vary in texture from coarse sand and gravel to heavy clay loam. The underlying glacial drift is well supplied with lime and is easily penetrated by the roots of most plants (Johnsgard et al., 1942, p. 12).

As poorer drainage conditions are approached the following changes take place in the soil profile: (1) The surface horizon becomes thicker and darker, (2) gray and yellow colors become more prominent below the surface layer, (3) the contrast between horizons below the surface layer becomes less marked, and (4) the reaction below the surface soil tends to approach neutrality. The most poorly drained mineral soils possess the following type of profile: (1) Very dark gray or black material, high in organic matter, and in many places more than 5 inches thick; (2) a horizon of gray or bluish-gray materials, mottled with yellow and rust brown, grading into materials similar to those underlying the well-drained soils, with no sharp line of demarcation. Organic soils represent an excessive accumulation of organic materials over the mineral soil materials as a result of very poor drainage or the filling of former lakes with vegetation (Johnsgard et al., 1942, p. 13).

The soils of Clinton County are evaluated as being of medium to high fertility "for this part of Michigan" and the distribution pattern of soil types is judged to be rather complex. These soils are divided into three main groups according to their location and composition: (1) Mineral soils of the uplands and terraces; (2) soils of the stream bottoms; and (3) organic soils.

The previous several paragraphs are indicative of the thoroughness of this report in describing the general survey area, the climate, and the general soil conditions. In addition to the material mentioned

here there is a good discussion of agricultural history and statistics and, under the heading "Soils and Crops," an adequate discussion of crop-soil adaptation.

A section of this report is concerned with productivity ratings and is introduced in the following manner:

> The soils of Clinton County are rated in table 7 according to their productivity for the more important crops and are listed in the order of their general productivity under common practices of management, the most productive first. Ratings are given for two general levels of management - the common and the better practices. In evaluating individual soil types, as mapped, the purity of the type is a modifying factor.[1] The description of the individual soils in the preceding pages should be consulted.

The productivity index compares each soil to a standard of 100 which represents the average acreage yield obtained without amendments on the more extensive and better soil types of the regions of the United States in which the crop is most widely grown. An example of production without amendments for selected crops, which is considered standard, is given below:

Corn	- 50 bushels
Wheat	- 25 "
Beans	- 25 "
Potatoes	- 25 "
Alfalfa hay	- 4 tons
Sugar beets	- 12 "

In addition to rating soils for crop productivity at two management levels, the table also comments on use, crops (adaptability), type of farming, workability, and erodibility. In the last column the soils are rated as to their best suitability such as, "Excellent cropland, fair to poor cropland, and wood lots and pasture land." Productivity indices were established from estimates based on

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[1]My italics

interviews with farmers rather than measured yields.

The section entitled "Land Use and Agricultural Methods" is based on a map showing distinctive "land types" of Clinton County. It is a forerunner of the modern soil association maps. Accompanying the map is a general discussion of soil characteristics, land use and suitability, management practices and recommendations, fertility recommendations, suggestions for erosion control, drainage, rotations, and crop varieties.

The Clinton County report contains a fairly complete section on the morphology and genesis of soils. That Clinton County is in the Gray-Brown Podzolic region serves as a basis for a discussion of climate in relation to soil formation. Original vegetation is identified as a dense forest of deciduous trees, relief is largely a level to gently rolling plain, a result of surface configuration which represents an early stage of the erosion cycle; time is fixed at several thousand years for residual soils; leaving the fifth soil-forming factor - parent material - to be analyzed in the following passage:

> The parent material of the soils consists of medium-to heavy-textured calcareous drift of the late Wisconsin glacial period. The drift covering is sufficiently thick to mask completely any direct influence of the underlying bedrock on the soils, except in one small area mapped as Berrien sandy loam in the southern part of Eagle Township. The drift consists of the transported residue of weathering material and rock fragments of shales, limestones, and sandstones, with smaller proportions of crystalline rock materials from more distant sources included. Till plains, terminal moraines, outwash plains, glacial lake-bed plains, and broad valleys, outlets for old glacial lakes, represent the major physical features in the county. The till, for the most part, is heavy in texture; the terminal moraine deposits are variable petrologically, but intermediate textures dominate, and sand, gravel, and boulders are included. The outwash plains and valleys are characterized by sandy and gravelly materials, and the lake plains display

a considerable range of texture of surface soil materials, which generally are underlain by till clay.

The most striking feature in the section on soil morphology and genesis is the completeness of the description of Miami loam as observed in De Witt Township and considered representative of a well-drained Gray-Brown Podzolic soil of the region. This description follows:

A_{oo} A 1-inch cover of freshly fallen beech, maple, and oak leaves.
A_o A 1/2-inch layer of brown moist partly decomposed leaves and leaf fragments.
A_1 0 to 4 inches, dark brownish-gray friable moist loam having a somewhat coarse crumb structure in place but crumbling to a friable mass on removal. Some earthworm holes and casts are present, and lighter colored materials fill many of the worm holes. The material is medium to high in finely divided organic matter. Small tree roots and grass roots are numerous. The pH value is 5.5 to 6.0. Small fingers of this dark soil may extend 1 to 2 inches into the next lower horizon.
A_2 4 to 8 inches, medium grayish-yellow slightly vesicular moist friable loam having a weak platy structure in the upper part but becoming coarsely granular in the lower part. This material is somewhat brittle and breaks down to a fine crumb structure under slight pressure. It is definitely brittle and powdery when dry. Some streaks of darker colored materials from the horizon above occur in worm holes and root holes. Roots are much less numerous than in the A_1 horizon. The pH value is 5.0.
B_1 8 to 12 inches, medium grayish-yellow, somewhat vesicular, moist, friable loam, splotched with yellowish-brown somewhat coherent more clayey material of an angular-granular structure. The more clayey yellowish-brown material increases in amount with depth. Some streaks of darker materials occur in worm holes and root holes. Grass and tree roots are numerous. The pH value is 5.0.
B_{21} 12 to 24 inches, yellowish-brown or reddish-brown moist coherent clay loam slightly streaked with lighter colored material in the upper part but becoming uniformly brown at a depth of about 15 inches. This material is sticky when wet. Angular nut-sized fragments from one-quarter to one-half inch in diameter break readily under pressure, showing a lighter yellowish brown color on the inside. Coatings of darker brown occur on faces of the aggregates and walls of root channels. Some darker materials from the surface layer are in root holes and worm holes. Roots are plentiful in the upper part of the layer but less numerous in the lower part. Roots are concentrated mainly on the cleavage faces of the

a considerable part of [illegible] soil materials, which generally are [illegible] clay.

The most striking features of the section on soil morphology

and genesis [illegible] the description of [illegible]

[illegible]

aggregates, but there is some penetration of the aggregates by roots. The pH value is 5.5.
B_{22} 24 to 42 inches, brown, dark-brown, or slightly reddish brown moist sandy clay loam having similar structure to that in the B_{21} horizon. This material is somewhat more friable on removal and less sticky when wet. Grass and tree roots are less numerous than in the B_{21} horizon. The pH value is 5.5. The material is somewhat streaked with yellow in the lower part.
C_2 42 inches +, yellowish-gray or grayish-yellow calcareous friable heavy loam or sandy clay loam glacial till having a fragmentary structure. Few roots are in this layer. The pH value is 7.5. Carbonates are present.

Small gravel stones occur throughout the entire soil mass. Miami loam has developed from materials of intermediate texture under conditions of good external drainage. The profile has a mild humous (sic) or mull type of A horizon, a highly siliceous eluviated A_2 horizon, and a B horizon of concentration of fine materials, largely clayey compounds of iron and aluminum. Bases have been sufficiently depleted to allow a slightly acid reaction to prevail throughout the solum, and the destabilization of fine material in the A horizon has been sufficient to allow translocation. The brown color of the B horizon suggests that aeration has allowed considerable oxidation of iron compounds in that horizon; but lack of a uniformly red color, such as is possessed by the most highly oxidized iron compounds, suggests that oxidation may not be complete or that dehydration has not advanced very far. Part of the apparent concentration of clay in the B horizon may be due to the removal of bases rather than entirely due to accumulation of translocated clay. A concentration of translocated clay is suggested by the colloidal coatings on the outsides (sic) of the aggregates in the B horizon. Possibly the conditions under which deflocculation of iron compounds took place and the size of the colloidal iron particles may have been responsible for these differences in color.

The preceding description identifies in a satisfactory manner the set of characteristics which form the taxonomic unit identified as Miami loam. The mapping unit, however, is discussed under the soils and crops section in the following manner:

Miami loam

...to plow depth, medium grayish-brown friable loam, slightly acid in reaction and medium to low in organic matter;... [7 to 13 inches of] light grayish-yellow friable loam, medium to strongly acid in reaction...[13 to 36 or 48 inches of] yellowish-brown compact clay loam, sticky when wet, but aggregates, but there is some penetration of the aggregates by roots. The pH value is 5.5.

B22 24 to 42 inches, brown, dark-brown, or slightly reddish-brown moist sandy clay loam having similar [illegible] to that in the B21 horizon [illegible] [illegible] breaking to firm angular particles, less than one-half inch in their greatest dimension, when dry. This material is medium to slightly acid in reaction...[underlain by] yellowish-gray calcareous loam or clay loam parent material having a coarser structure than [the previous horizon].

[Notes and inclusions]

A small quantity of gravel and a few stones are common throughout the entire soil mass. Roots of the common crop plants penetrate the soil with ease, and many reach a depth of more than 5 feet. The greatest concentrations of roots are in horizons 1 and 3. Soil having this profile, or slight variations from it, covers a large portion of the area mapped as Miami loam;...numerous variations, individually of small extent but collectively occupying from 25 to 50 percent of some areas[1], occur as part of the unit. Included small depression and level areas in many places approach the Conover and Brookston soils in profile characteristics. Some small sandy spots resembling Hillsdale and other sandy soils are included.

Erosion has...[exposed the] underlying clay loam material [in some places]...[with the] deposition of material on lower slopes and in depressions.... [It] is mapped as Washtenaw loam where the areas are sufficiently large to be mapped as separate units.... [The Miami loam unit] occurs in nearly all parts of the county, [but] it is best developed and most extensive in the southern townships.... [The topography is] undulating to gently rolling... Although Miami loam is lower in content of essential plant nutrients and lower in moisture-retaining capacity than some of the more poorly drained soils, it is well above the average for the group of well-drained soils in both respects.

The soil mass is easily penetrated by roots, and the presence of an abundance of lime at a comparatively slight depth insures...[a sufficiency] of this material for most plants. Good tilth can be maintained with little difficulty.

In addition to the aforementioned information about the mapping unit, there is a discussion of natural vegetation, crop adaptation and management, fertilization rates, erosion control, and drainage. Once having ingested all this information about Miami loam, the reader should have a pretty good concept of the nature of the beast

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[1]My italics

when encountered either in the map and report or in the field.

In the discussion of the imperfectly drained series, Conover loam, the statement regarding mapping unit inclusions is worthy of consideration:

> As the characteristics of the Conover soils are intermediate between those of the Miami and Brookston soils, variations approaching these two soils are common in areas mapped as Conover loam. Some small sandy spots approaching Berrien sandy loam in character are included, and in places a small quantity of gravel is scattered over the surface. The lower areas of Conover loam are rather uniform in character, but considerable variation exists where this soil is mapped in a transitional position between the well-drained and poorly drained soils or as a border around swamps.

The map accompanying the Clinton County report is printed in a 24 inch x 24 inch space. This is the soil survey information for a county of 16 townships or 571 square miles. The soil survey information is superimposed over a section line grid and contour intervals of two intensities (5 and 10 feet). Although contour lines are shown in brown and soil delineation lines in black, a comparison of map areas with and without contour lines quickly demonstrates that they make the map too complicated to be easily legible at the 1 inch = 1 mile scale.

Some peat or muck areas may include several square miles in a single delineation; however, for the major portion of the survey area, sections contain from 10 to 30 + delineations with the average being perhaps 20 to 25. A cursory inspection of this map will reveal that it would be difficult to show more detail at the 1:62500 scale.

The text of the Soil Survey Report of Sullivan County, Tennessee (Matzek et al., 1953), at 199 pages is nearly three times as long as the Clinton County, Michigan, report, and this is for a

county with only 75% as much land area. Some of this difference in report length can be attributed to factors such as the relative complexity of the areas and the writing style of the authors. Probably the most influential factor, however, is the progress made in soil survey technique and analysis in the 8 years between 1936 and 1944, the years in which these surveys were completed.

In addition to the information given in the Clinton County, Michigan, soil survey, the Sullivan County, Tennessee, survey has a section on how to use the soil survey report, discussions on water supply, forests, and factors of soil formation.

The section on how to use the report is well written in simple, easily understood language. By way of example the introduction is given below:

> Farmers who have worked with their soils for a long time know about soil differences on their own farms and perhaps on the farms of their immediate neighbors. What they do not know, unless soil surveys have been made, is how nearly their soils are like those at experiment stations or on other farms, either in their State or other States, where farmers have gained experience with new or different farming practices or farm enterprises. They do not know whether higher yields obtained by farmers in other parts of their county and State are from soils like theirs or from soils so different that they could not hope to get yields as high, even if they followed the same practices. One way for farmers to avoid some of the risk and uncertainty involved in trying new production methods and new varieties of plants is to learn what kind of soils they have so that they can compare them with the soils on which new developments have proved successful.

Following this are detailed instructions on how to use the soil map in conjunction with the various parts of the survey report. Perhaps the other most important user of the soil survey is identified near the end of the section:

> A newcomer to the county, especially if he considers purchasing a farm, will want to know about the climate;

the types and sizes of farms; the principal farm products and how they are marketed; the kind of conditions of tenancy; kinds of farm buildings, equipment, and machinery; churches, schools, roads, and railroads; the availability of telephone and electric services and water supplies; the industries of the county; and about towns, villages, and population characteristics. Information on all of these will be found in the sections on General Nature of the Area and Additional Facts About Sullivan County.

Although this section does not specify the fact, the soil survey is just as valuable for a farmer who is interested in purchasing another farm in the county or, more generally, anyone who is interested in working with the land for any purpose.

In the section on physiography, relief, and drainage there is a map showing physiographic divisions of the county. Six divisions are listed in the accompanying text with discussions of the physiography (land form), underlying geology, and major soil types mapped in the area.

The section on water supply is a general survey of water resources for residential, industrial, and recreational use. No attempt has been made to recommend guidelines in water resource development.

In the section entitled "Land Classification, Soil Management, and Productivity," under a sub-heading of "Land Classes," five different classes of soils are established to rate all the soils of the county in regard to their suitability for a particular use - in this case farming. Criteria for placement of a soil into an individual class are workability, conservability, and productivity. Placement was made subjectively by the use of information obtained from farmers and professional workers, and by consideration of soil characteristics such as: organic matter content; nutrient level;

water holding capacity; texture, structure, and consistence; slope; stoniness; and natural drainage.

Under the sub-heading "Soil Management," the soils of the county are placed in one of 19 management groups. Criteria for placement in a particular group are general productivity, workability, and conservability.

In the section treating estimated yields, common crop yields at two management levels on each soil type are estimated from observation, interviews, and experience in the area. In this section yields are indicated in the normal unit of measurement rather than as an index numeral.

The section entitled "Soil Associations," contains a soil association map of Sullivan County. A soil association map is defined as a generalized map showing groups of geographically associated soils, each group having a fairly uniform pattern of relief, drainage, use suitability, and component soils throughout its extent. The purpose of the map is "to show, by generalization, areas dominated by various geographically related soils." The soil association unit is an important unit because it indicates the size and type of farm contained therein, the type of crops grown, and the intensity of management of those crops. It is possible for one soil type to occur in several associations, but only in one association in delineation units large enough to be suitable for the intensive cultivation of a particular crop.

The discussion of the "Dunmore-Dewey" association begins with the general physiographic setting, type of drainage, and position on the landscape of the component soils.

water-holding capacity; texture, structure, and stone content; slope; steepness; and natural drainage.

Under an accompanying detailed description of the soils of the [illegible] criteria for

> The Dunmore soils are the most extensive and occur with Dewey and Decatur soils in the smoother parts of the association. The cherty Dunmore soils generally occupy the slightly steeper, low-lying ridges. The Hermitage and Pace [soils] occupy benches and colluvial fans slightly above the Emory, Greendale, and Lindside soils, which form narrow belts along the streams.

A discussion of crop suitability, cropping systems, and productivity follows along with farming enterprises, erosion hazards, and related problems. In all there are 10 soil associations in Sullivan County.

Under "Additional Facts About Sullivan County," are discussions about land use; crops, including specific information about the production and management of corn, hay, wheat, and minor crops; rotations and fertilizers; and other items of interest to persons concerned with the agricultural enterprise.

The section on forests is divided into sub-sections entitled "Forest Types," "Forest Production," and "Forest Management." Forest management involves discussions on fire prevention, control of grazing, cutting practices, and plantings.

Under "Morphology, Genesis, and Classification of Soils," the factors of soil formation-parent material, climate, vegetation, relief, and time - are treated as separate, equally effective agents. The sub-section on classification divides the soils into zonal, intrazonal, and azonal orders, and subdivides them under their proper great soil group. Under each great soil group is listed the series contained therein with columns giving dominant relief, parent material, outstanding characteristics, and time. Each great soil group is discussed in detail in the body of the section, and representative series descriptions are included in the

discussion.

In the decade previous to 1944, the date of this survey, considerable progress had been made in soil survey methods. The stated policy of soil survey methods and definitions, as given in this report, indicates the degree of sophistication the discipline had acquired and gives clues to possible weaknesses inherent in the system.

> Soil Survey Methods and Definitions
>
> Soil surveying consists of the examination, classification, and mapping of soils in the field. The soil scientist walks over the area at intervals not more than a quarter of a mile apart and bores into the soil with an auger or digs holes with a spade. Each such boring or hole shows the soil to consist of several distinctly different layers, called horizons, which collectively are known as the soil profile. Each of these layers is studied carefully for the things about it that affect plant growth.
>
> The color of each layer is noted. The darkness of the topmost layer is usually related to its content of organic matter; streaks and spots of gray, yellow, and brown in lower layers generally indicate poor drainage and poor aeration. Texture, or the content of sand, silt, and clay in each layer, is determined by the feel and checked by mechanical analyses in the laboratory. Texture has much to do with the quantity of moisture the soil will hold available to plants, whether plant nutrients or fertilizers will be held by the soil in forms available to plants or will be leached out, and how hard the soil may be to cultivate.
>
> Structure, or the way the soil granulates, and the number of pores or open spaces between particles indicate how easily plant roots penetrate the soil and how easily water enters it. Consistence, or the tendency of a soil to crumble or stick together, indicates how difficult it is to keep the soil open and porous under cultivation. The kind of rock and the kind of parent material from which the soil has been developed affect the quantity and kind of plant nutrients the soil may have naturally. Simple chemical tests show how acid the soil may be. The depth to bedrock or to compact layers is determined. The quantity of gravel or rocks that may interfere with cultivation, the steepness and kind of slope, the quantity of soil lost by erosion, and other external features are observed.

discussion.

In the decade previous to 1945, the span of this survey,

considerable progress [illegible] in soil survey methods. The

On the basis of all these characteristics, soil areas much alike in the kind, thickness, and arrangement of layers are mapped as one soil type. Some soil types are separated into two or more phases. For example, if a soil type has slopes ranging from 2 to 12 percent, the type may be mapped in two phases, an undulating phase (2 to 5 percent slopes) and a rolling phase (5 to 12 percent slopes). Likewise, a soil that has been eroded in places may be mapped in two or more phases, an uneroded phase (denoted by absence of reference to erosion in the name), an eroded phase, and perhaps a severely eroded phase. A soil type will be broken into phases primarily because of differences in the soil other than those of kind, thickness, and arrangement of layers. The slope of a soil, the frequency of outcropping bedrock, the extent of erosion, or artificial drainage are examples of characteristics that might cause a soil type to be divided into phases.

Two or more soil types may have similar profiles; that is, the soil layers may be nearly the same, except that the texture, especially of the surface layer, will differ. As long as the other characteristics of the soil layers are similar, these soils are considered to belong in the same soil series. A soil series therefore consists of all the soil types that have about the same kind, thickness, and arrangement of layers, except for texture, particularly of the surface layer, whether the number of such soil types be only one or several.

The name of a place near where a soil series was first found is chosen as the name of the series. Thus Dunmore is the name of a yellowish-red, moderately plastic, well-drained acid soil series found on the residuum of limestone and dolomite in Sullivan County, Tennessee. Six types of Dunmore series are found - Dunmore cherty silt loam, Dunmore cherty silty clay loam, Dunmore loam, Dunmore silt loam, Dunmore silty clay loam, and Dunmore stony loam. These types differ in the texture of the surface soil, as their names show, and are divided into phases as uneroded, eroded, and severely eroded and rolling, hilly, and steep because of differences in erosion or slope.

Areas such as bare rocky mountainsides, where there is little true soil, are not designated with series and type names but are given descriptive names. Rough gullied land (limestone material) and Stony colluvium (Jefferson soil material) are two such units mapped in this county.

The soil type, or where the soil type is subdivided, the soil phase, is the unit of mapping in soil surveys. It is the unit or the kind of soil that is most nearly uniform and has the narrowest range of characteristics. For this reason land use and soil management practices can be more definitely specified for the type or phase than for border groups of soils

containing more variation. One can say, for example, that soils of the Dunmore series need lime for alfalfa; but more specifically it can be said that Dunmore cherty silt loam, rolling phase, has mild slopes and, in addition to needing lime, is suited to row crops in a rotation with small grains and hay; or that Dunmore cherty silt loam, hilly phase, has slopes that fall more than 12 feet in 100, is hard to work with heavy machinery, erodes easily, and should be used principally for close-growing crops. Both of these phases are included in the Dunmore series.

Descriptions of soil types in this report are not exceptional and descriptions of the mapping units are inadequate. In this respect the report falls far behind the Clinton County, Michigan, report of a decade earlier. An example is the following description:

Needmore silt loam, eroded rolling phase: 0 to 5 inches, light yellowish-gray friable silt loam; brownish-gray when moist. 5 to 22 inches, reddish-yellow firm moderately tough and plastic silty clay. 22 to 34 inches, variegated yellowish-red, red, olive, yellow, and gray silty clay containing soft weathered shale fragments; olive-gray calcareous shale bedrock at a depth of about 3 feet.

[Notes and inclusions]

This upland soil is developed from calcareous shale materials and occupies relatively broad smooth ridge crests in areas of Dandridge soils. It differs from the Dandridge soils in being deeper and more acid and in having more distinct surface and subsoil layers. Also, its subsoil usually is redder and somewhat finer textured. Slopes range from 5 to 15 percent in most places but are less than 5 percent in a few areas. Erosion has removed part of the original surface layer, and in cultivation the rest has been mixed with the upper subsoil. The soil is medium to strongly acid and low in fertility. It is well-drained, but the moderately plastic consistence of the subsoil makes it only moderately permeable to roots and moisture.

....

The subsoil is usually reddish yellow but it may be brownish yellow in some places, and in a few, yellowish red. The substratum varies from a few inches to not more than 12 inches thick.

Following this description is nearly three-fourths of a page devoted to use and management of this mapping unit. Considering

the amount of space devoted to use and management of the individual soils elsewhere in the report, the repetition of it here approaches redundancy. Likewise, one wonders about the lack of A-B-C horizon nomenclature here and elsewhere in the report. The most serious omission, however, is in the lack of identification of mapping unit composition and inclusions.

This report is outstanding in the excellent photographs showing soil associations, use, and production of farm crops. The photographer composed landscape shots in crisp detail and thoughtful content. His shots of erosion and rockiness are of highest quality. However, there is not a single photograph of a soil profile in the report.

The scale of the published map is 1:20000 or approximately 3.2 inches = 1 mile. This forced publication on 9 sheets, each approximately 24 x 30 inches. In addition, the larger scale was evidenced in a tremendous increase in detail. In some of the mountainous areas one delineation may contain a square mile; in others a square mile may contain as many as 100 separate delineations.

F. MODERN SOIL SURVEYS

The Soil Survey of Fairfax County, Virginia (Porter et al., 1963), lying just to the south and west of Washington, D.C., was one of the first, if not the first, areas in the United States to be surveyed with the specified purpose being urban development (Kellogg, 1966, p. 6). The stated purpose of progressive soil surveys from the beginning had been the acquisition of fundamental scientific soil information, classification of soils on the basis of fundamental characteristics, and the plotting of soil units in the

field on this basis. However, it had developed a distinctly agricultural flavor which was inevitable considering the long and close association between the study of soils and agricultural enterprise.

It was becoming increasingly apparent that the fundamental scientific information contained in a progressive soil survey map and report could be interpreted for urban as well as agricultural uses. With this in mind the county supervisors of Fairfax County, Virginia, in the early 1950's, requested Virginia Polytechnic Institute and the U.S.D.A. Soil Conservation Service to make a soil map and report for their county to serve as a guide for the inevitable approach of urbanization. To aid in this endeavor, Fairfax County pledged $30,000.00 toward the cost of the survey (Obenshain, 1966, p. 175). The survey was begun in 1952 and completed in 1955. The field sheets were reproduced as soon as completed and interpretations for either urban development or special agricultural purposes were made available for immediate use (Robinson, Porter, and Obenshain, 1955).

While the contents of the Fairfax report differ significantly from the Sullivan County, Tennessee, report only in the addition of a section on engineering properties of the soils, a glossary, and modification of the system of land classes, the format is considerably changed. The size was expanded from 6 x 9 inches to 9 x 11 inches. Instead of large multi-folded sheets contained in a pocket in the back cover, the soil maps were smaller, single-fold sheets at the end of the report. Most important, the soil maps were printed on a photographic base rather than plain paper, a boon to pinpointing

CLAM on this basis, however, it has developed a distinctly agricultural flavor which was inevitable considering the long and close association between the study of soils and agricultural enterprises.

It has become increasingly apparent that the fundamental scientific information contained in a progressive soil survey may locations.

The section entitled "Engineering Properties of the Soils," contains subheadings entitled "Soil Test Data" (including engineering soil classification systems), "Suitability of Soils for Engineering Uses," and "Suburban Uses of Soil Survey Information." This section states that information contained in the soil survey report can be used by engineers to:

1) Make soil and land-use studies that will aid in the selection and development of industrial, business, residential, and recreational sites.
2) Make preliminary estimates of the engineering properties of soils in planning agricultural drainage systems, farm ponds, irrigation systems, and diversion terraces.
3) Make reconnaissance surveys of soil and ground conditions that will aid in locating highways and airports and in planning detailed soil surveys for their intended locations.
4) Locate sources of sand and gravel.
5) Correlate pavement performance with types of soil and thus develop information that will be useful in designing and maintaining pavements.
6) Determine the suitability of soil units for cross-country movement of vehicles and construction equipment.
7) Supplement information obtained from other published maps and reports and aerial photographs, for the purpose of making soil maps and reports that can be used readily by engineers.
8) Estimate the nature of material encountered when excavating for buildings and other structures.
9) Determine the suitability of soils for septic-tank sewage disposal systems.

Immediately following the previous statements, however, is the italicized warning:

> The mapping and the descriptive report are somewhat generalized, however, and should be used only in planning more detailed field surveys to determine the in-place condition of the soil at the site of the proposed engineering construction.

Most of the soil types mapped in Fairfax County were sampled in all their major horizons and tested by the Bureau of Public Roads. The following tests were conducted: mechanical analysis by a

combination of sieving for larger particles and the hydrometer method for finer particles, maximum dry density and optimum moisture, liquid limits, and plasticity index. Then the soils were classified under both the A.A.S.H.O. (American Association of State Highway Officials) and Unified systems. Those soils not tested were placed into categories in each system by estimation.

Under the sub-heading "Soil Test Data," test procedures and results are explained. Although mechanical analysis by the hydrometer method used here is satisfactory for engineering purposes, results of these analyses are not acceptable for naming textural classes in characterization for soil classification. Liquid limit is defined as the moisture content at which soil passes from a liquid to a plastic state. Plasticity index is the numerical difference in moisture content between liquid limit and plastic limit. It represents the moisture range over which the soil is plastic. In the moisture-density procedure, repeated compaction of a sample at varying moisture levels yields values indicating the maximum dry density to which a soil can be compacted and the moisture content at which such compaction may be achieved. The A.A.S.H.O. and Unified systems of engineering soil classification are explained under a separate sub-heading.

The sub-heading "Suitability of Soils for Engineering Uses," is largely concerned with explaining Table 7: "Features and estimated quality of soils for engineering construction." Each soil has been tested to give percolation rates; evaluated as to shrink-swell potential; rated as to suitability as a source of topsoil, sand and gravel, road fill, and suitability for septic tank drainage

fields; and judged as to features affecting airport and highway location, footings for single family dwellings, and farm pond reservoir areas and embankments.

Percolation rates were determined in actual field tests; shrink-swell potential indicates the change in soil volume that can be expected with a change in moisture content and is estimated by the amount and kind of clay in the soil; topsoil is the normal surface soil, usually rich in organic matter, and is used to topdress roadbanks, lawns, and gardens (it is rated on the basis of texture and organic material); suitability of a soil as a source of sand or gravel is based on knowledge of soils that have provided suitable construction material in the past; suitability of a soil for roadfill depends upon its texture and natural water content; septic tank drainfield suitability depends upon percolation rates which measure the rate at which water will seep into a soil at tile-line depth, and other soil features such as depth to bedrock, hardpan, and perched water-table.

Factors involved in the location of airports and highways are:

1) Stability of slopes and embankments
2) Bearing capacity
3) Shrink-swell potential
4) Erodibility
5) Presence of bedrock near the soil surface
6) Stoniness
7) Steep slopes
8) High water table
9) Flooding
10) Seepage

Soil characteristics important in relation to footings for family dwellings are:

1) High water table
2) Topographic position (flood-plain, terrace, etc.)
3) Bearing capacity
4) Shrink-swell potential
5) Stability

6) Presence of hard rock near the surface

Soil features considered important in location of farm pond reservoirs are: "Permeability of the soil, the rate of seepage, and the depth to rock or permeable material." In rating soils for farm pond embankments the following are important: "...permeability, texture, strength, and stability of the soil material."

The sub-section entitled "Suburban Uses of Soil Survey Information," lists the soil survey as aiding in the location of "...land that has desirable characteristics for schools, roads, residential areas, agriculture, drainageways, flood plains, industry, and other public and private facilities."

The system of five land classes outlined and used in the Sullivan County, Tennessee, report had been modified to become the Land Capability Classification System by the U.S.D.A.,Soil Conservation Service. It was used extensively by soil conservationists in conservation farm planning by the time the Fairfax County, Virginia, survey was published. It is a fairly simple system in which all soils are grouped into eight broad classes according to their potential and limitations for a number of agricultural and other non-urban uses. Capability sub-classes specify the type of use-limiting factor, while the more specific capability unit, which is in reality a management unit and may include one or several soils, serves as the basic planning unit.

In the Fairfax County report, capability classes, sub-classes, and units are given with accompanying crop suitability, suggested rotations, fertility management, tillage management, and recommended supplementary water-control practices. Symbols for the capability

d) Fractures in hard rock near the surface

5b. Well fractures [illegible] important in [illegible]

[illegible] of the well, the rate of [illegible]

and the [illegible]

units are given along with the mapping unit symbols at the rear of the report.

Although the New Classification System had been published nearly three years earlier than the date of this report, the 1938 System of Classification, with modifications, is used here. As an example consider the Glenelg series which is, under the 1938 System, a Gray-Brown Podzolic - Red-Yellow Podzolic Intergrade:

Glenelg Series

The Glenelg series consists of well-drained, brown soils on undulating to rolling upland. The parent rock is fine-grained, micaceous schist. The Glenelg soils are associated with the Elioak, Manor, and Glenville soils. Compared with the Appling soils, they have a browner solum and are in a thicker regolith. A few areas have a lighter-than-normal solum, and these soils represent an intergrade toward the Red-Yellow Podzolic profile. Glenelg soils are strongly acid and are notably high in potassium.

Profile of Glenelg silt loam, undulating phase (in a wooded area located 1/4 mile east of Dranesville, Va., along State Highway No. 7):

A_0 2 inches to 0, dark reddish-brown (5YR 2/2), well-decomposed, matted small roots and leaf litter.
A_1 0 to 2 inches, dark-brown (7.5YR 4/2), friable silt loam; weak, fine, granular structure; many roots.
A_2 2 to 7 inches, yellowish-brown (10YR 5/4), friable silt loam; weak, fine, granular structure; numerous small roots.
B_1 7 to 13 inches, strong-brown (7.5YR 5/6), friable silty clay loam; moderate, fine to medium, subangular blocky structure; few, faint, medium mottles of light brown and yellowish red.
B_2 13 to 22 inches, yellowish-red (5YR 5/6), friable silty clay loam; moderate, fine, subangular blocky structure; mica flakes common; roots numerous; few small angular fragments of quartz and small fragments of schist.
B_3 22 to 28 inches, yellowish-red (5YR 5/6), very friable micaceous, light silty clay loam; weak, fine to very fine, subangular blocky structure; small roots common.
C 28 to 72 inches, mottled light reddish-brown (5YR 6/4), light-gray, gray, pink, and yellowish-red, soft, micaceous, silty clay schist soil material; no definite structure; some of the freshly weathered schist has fine, laminated rock structure.

units are given along with the mapping unit symbols at the end of the report.

Although the new classification system had been published [illegible] quently three [illegible] date of this report, the 1959

The previous description of the Glenelg series is accompanied by only one reference to range in characteristics - that "a few areas have a lighter-than-normal solum." However, following the description of "Glenelg silt loam, undulating phase," is the next passage:

> Range in characteristics - The surface layer ranges from yellowish brown to dark brown in cultivated areas and from very pale brown to dark grayish brown in wooded areas. The subsoil is predominately strong brown to yellowish-red, and it is generally lighter colored in wooded areas. The thickness of the subsoil ranges from 10 to 20 inches. In places quartz pebbles and angular cobbles on and in the soil are numerous enough to interfere greatly with tillage. Very small areas of the Elioak and Manor soils and of reddish-brown soils similar to the Myersville soils (not mapped in Fairfax County) that have formed from more basic rock material are included with Glenelg silt loam, undulating phase. Small areas that have a loam surface layer are also included. In addition, a small acreage of Manor silt loam, undulating phase (not mapped separately in Fairfax County), has been included with this soil.
>
> Nearly all the acreage, particularly that in cultivation, has lost small to moderate amounts of soil through sheet erosion, and in places the subsoil is exposed. However, Glenelg silt loam, undulating phase, has lost less surface soil than the Elioak and Manor soils. This soil is very strongly to strongly acid, contains a fairly small amount of organic matter, is moderate to low in natural fertility, and is fairly susceptible to erosion.
>
> This soil is relatively high in potassium and is fairly retentive of added plant nutrients. It is not so retentive as the Elioak soils but is more retentive than the Manor soils. Less lime is needed to raise its pH to a given level than is needed for the Elioak soils. The permeability of the surface soil is rapid; that of the subsoil is moderate to moderately rapid. The water-holding capacity is moderate.

In the general discussion of the Glenelg series preparatory to the specific discussion of Glenelg silt loam, undulating phase, the Glenelg soils are said to differ from the Elioak soils in containing more mica, having a thinner profile, and having less clay and being less red in the subsoil. Compared to the Manor soils, the Glenelg

soils have a better developed profile.

As mentioned previously, the soil map at a scale of 1:20,000 is published on an aerial photographic base-one which permits identification of land and cultural features such as streams, forests, individual trees, fense lines, roads, houses, and many others - and which makes orientation much simpler.

The amount of detail varies according to soil pattern from about 40 to 150 delineations per square mile, with the average being about 130 per square mile.

Field work for the Soil Survey of Westmoreland County, Pennsylvania (Taylor et al., 1968) was done in the period 1957-1962 and the report was published in 1968. Since precedent had been set in having soil survey information in a particular county used primarily for urban purposes, and since Greensburg, the county seat of Westmoreland County, is only 25 miles from Pittsburg, it should be safe to assume this survey falls in the general category of "urban soil surveys." Certainly any planning official studying population trends in the section "General Nature of the Area," would be forced to conclude the county was "rapidly urbanizing" at least. The following figures are indicative of the county trends:

	1950	1959	1960
Population	--	313,179	351,735
Rural Population	19,286	--	7,333

Although Westmoreland County is large - 1040 square miles - the population far exceeds the normal density of a rural or agricultural county in this region. If the total land area of 665,600 acres were divided evenly there would be 4160 farms of 160 acres each in the county. Assuming a farm family of 5 on each unit, could have a better developed profile.

As mentioned previously, the soil map at a scale of 1:20,000 is published on an aerial photograph base [illegible] which provides [illegible] the total population would be 20,800 which is a far cry from more than a third of a million.

Certain modifications have been made in the section "How This Soil Survey Was Made," especially in the discussion of the concept of the mapping unit. It begins in the following manner:

> Soil scientists made this survey to learn what kinds of soils are in Westmoreland County, where they are located, and how they can be used.
>
> They went into the county knowing they likely would find many soils they had already seen and perhaps some they had not. As they traveled over the county, they observed steepness, length, and shape of slopes; size and speed of streams; kinds of native plants or crops; kinds of rock; and many facts about the soil.

A general discussion of the soil profile, soil series, type, and phase follows until the actual geographically delineated unit, the mapping unit, is considered:

> After a guide for classifying and naming the soils had been worked out, the soil scientists drew boundaries of the individual soils on aerial photographs. These photographs show woodlands, buildings, field borders, trees, and other details that help in drawing boundaries accurately. The soil map in the back of this publication was prepared from the aerial photographs.
>
> The areas shown on a soil map are called mapping units. On most maps detailed enough to be useful in planning management of farms and fields, *a mapping unit is nearly equivalent to a soil type or phase of a soil type.*[1] It is not exactly equivalent, because it is not practical to show on such a map all the small, scattered bits of soil of some other kind that have been seen within an area that is dominantly of a recognized soil type or soil phase.
>
> In preparing some detailed maps, the soil scientists have a problem of delineating areas where different kinds of soils are so intricately mixed or occur in such small individual tracts that it is not practical to show them separately on the map. They show this mixture of soils as one mapping unit and call it a soil complex. Ordinarily a soil complex is named

---

[1]Italics mine.

> for the major kinds of soils in it, for example, Upshur-Gilpin silty clay loams.
>
> Most surveys include areas where the soil material is so rocky, so shallow, or so frequently worked by wind and water that it cannot be classified by soil series. These areas are shown on the map like other mapping units, but are given descriptive names, such as Gullied land or Made land, and are called land types.
>
> Another kind of mapping unit is the undifferentiated group, which consists of two or more soils that may occur together without regularity in pattern or relative proportion. The individual tracts of the component soils could be shown separately on the map, but the differences between the soils are so slight that the separation is not important for the objectives of the soil survey. An example is Burgin and Burgin gray surface variant, silt loams.

This is a fairly comprehensive explanation of the various units which appear on the soil map and of the manner in which they are derived. For the purpose of explaining how various interpretive groupings are made, the remainder of the section is quoted below:

> While a soil survey is in progress, samples of soil are taken, as needed, for laboratory measurements and for engineering tests. Laboratory data from the same kinds of soils in other places are assembled. Data on yields of crops under defined practices are assembled from farm records and from field and plot experiments on the same kinds of soils. Yields under defined management are estimated for all the soils.
>
> But only part of the soil survey is done when the soils have been named, described, and delineated on the map and the laboratory data and yield data have been assembled. The mass of detailed information then needs to be organized in such a way that it is readily useful to different groups of uses, among them farmers, foresters, and engineers. Grouping soils that are similar in suitability for each specified use is the method of organization most commonly used in soil surveys. The soil scientists set up trial groups based on yield and practice tables and other data. They test these groups by further study and by consultation with farmers, agronomists, engineers, and others; then they adjust the groups according to the results of their studies and consultations. Thus, the groups that are finally evolved reflect up-to-date knowledge of the soils and their behavior under present methods of use and management.

In the section "Use and Management of the Soils," is a sub-section on woodland. The most significant idea in this body of for the major kinds of soils in ... Gilpin silty clay loams.

Most surveys include areas where the soil material is so rocky, so shallow, or so frequently worked by wind and water ... classified by soil series.

material is the division of soils of the county into 10 woodland suitability groups. Factors considered in the formulation of these groups and in placement of soils into specific groups are: potential productivity as expressed by site index; seedling mortality; windthrow hazard (which indicates the chance of trees being blown over by winds); plant competition (or invasion by or growth of undesirable species); equipment limitation (including reference to type of equivalent and seasonal use restriction); and erosion hazard.

There is a sub-section on wildlife also under the heading, "Use and Management of Soils." An inventory of the wildlife population is given, along with an enumeration of the factors affecting their existence and well-being. In addition,there is a table rating each soil mapping unit as a wildlife habitat. Each mapping unit is rated according to its suitability for the various elements of wildlife habitat which are: grain and seed crops, grasses and legumes, wild herbaceous upland plants, hardwoods, conifers, wetland food and cover, shallow water development, and excavated ponds. Kinds of wildlife are listed as open-land wildlife, woodland wildlife, and wetland wildlife; and the suitability of each mapping unit for such species is indicated.

The third new sub-heading under the general heading "Use and Management of the Soils," is entitled "Community Development" and is an expansion of the topic "Suburban Uses of Soil Survey Information," described in the previously mentioned report. Again the salient feature of this topic is a table entitled "Interpretation for Recreation and Community Development." After each mapping unit, its degree and kind of limitations are enumerated for: disposal of

effluent from septic tanks, sewage lagoons, homesite locations, landscaping and lawns, streets and parking lots, athletic fields, parks and play areas, sanitary landfills, and cemeteries.

In 1965 the National Cooperative Soil Survey began using the New System of Soil Classification (7th. Approximation), along with the Modified 1938 System. Therefore, in the section "Formation and Classification of the Soils," each series is carried through the family, subgroup, and order categories of the New System, along with its placement in the great soil group of the 1938 System.

The Westmoreland County report contains a separate section entitled "Laboratory Determinations," with a table of data for 6 of the series found in the county, plus an explanation of the methods of analysis and a summary of the data. These series make up only about 22 percent of the soil area mapped in the county, so we must assume that interpretations for soils comprising the remainder of the area are based on data extrapolated from other counties.

The following analyses were run on each horizon of the pedons sampled: particle size distribution by pipette, coarse fragments, moisture content at 1/3 and 15 atmospheres tension, organic carbon, nitrogen, calcium, magnesium, sodium, potassium, hydrogen, cation exchange capacity, base saturation, pH, and percentages of kaolinite, illite, vermiculite, chlorite, montmorillonite, and interstratified minerals in the clay fraction. An example of the summary of data follows:

> Clarksburg soil - The sample shows a predominance of silt in most horizons and the largest clay content in the lower part of the B horizon and in the C horizon. The quantity and distribution of coarse fragments are evidence that the soil formed in colluvium. Because of the quantity and distribution of this coarse material and the high percentage of sand, the

material is well graded. The presence of a fragipan is reflected in an increase in bulk density with increasing depth. The moisture content at 1/3 atmospheres and at 15 atmospheres indicates that the soil should hold moderately large amounts of moisture available to plants, but the amount of available moisture above the fragipan is only moderate. The cation exchange capacity and the base saturation are moderate to low. In comparison with other soils in the county, this soil is moderate to low in extractable calcium and potassium and moderate to high in extractable hydrogen. The strongly acid reaction in the upper part of the profile, which is not typical of Clarksburg soils, can be explained by the fact that in parts of Westmoreland County these soils are near coke ovens and are made strongly acid by the acid fumes. Normally, Clarksburg soils are only slightly acid. The analyses show illite to be the dominant clay mineral. The interstratified component consists of montmorillonite and illite. There is also vermiculite-dioctahedral chlorite in the surface layer. This soil is similar to Upshur soils in mineralogy.

As an example of a modern soil series description, the following is quoted:

Monongahela Series

The Monongahela series consists of deep, medium-textured, nearly level to sloping, moderately well drained soils. These soils occur in two distinct topographic positions. They are low-lying flats close to streams and on high terraces about 30 feet or more above the valley floor. On the higher and older terraces, the soils are somewhat browner in the uppermost horizons, are brighter colored and more reddish in the subsoil, and are likely to have more sand and gravel in the lower part of the profile. Monongahela soils are associated with somewhat poorly drained Tygart soils and the poorly drained Purdy soils. Also nearby are the Atkins and Philo soils of the flood plain.

Monongahela soils developed in old alluvium derived mainly from acid soil material, The surface layer is dark grayish-brown silt loam. The upper part of the subsoil is yellowish-brown, heavy silt loam mottled with dark brown and light brownish gray. The lower part is a firm, brittle, moderately slowly permeable fragipan. It is yellowish-brown light silt loam or loam mottled with gray and light brownish gray. The substratum is yellowish-red fine sandy loam that is 10 percent gravel.

Most of the acreage is cropland or pasture. There are scattered woodlots.

The following representative profile of Monongahela silt

loam, 3 to 8 percent slopes, moderately eroded, is in a hay field in Bell Township 1 mile south of Salina.

Ap - 0 to 11 inches, dark grayish-brown (10YR 4/2) silt loam; weak, fine, granular structure; friable when moist, nonsticky and nonplastic when wet; pH 5.3; abrupt, smooth lower boundary. 10 to 12 inches thick.
B_{21t} - 11 to 18 inches, yellowish-brown (10YR 5/6) heavy silt loam; dark grayish-brown (10YR 4/2) coatings; moderate, medium, subangular blocky structure; thin, discontinuous clay films; firm to friable when moist, slightly sticky and slightly plastic when wet; pH 4.8; gradual wavy lower boundary. 5 to 9 inches thick.
B_{22t} - 18 to 24 inches, yellowish-brown (10YR 5/4) heavy silt loam; 2% rounded gravel; common, medium, distinct, light brownish-gray (10YR 6/2) and dark-brown (10YR 4/3) mottles; common black coatings; moderate, medium, prismatic structure breaking to moderate, medium, platy; thin, continuous clay films; firm when moist, slightly sticky and plastic when wet; pH 4.6, gradual, wavy lower boundary. 4 to 8 inches thick.
B_{x1} - 24 to 37 inches, yellowish-brown (10YR 5/6) light silt loam; 3 percent rounded gravel; common, medium, distinct, light brownish-gray (10YR 6/2) and brown (7.5YR 5/4) mottles; coarse prismatic structure breaking to strong, medium, platy; thick, discontinuous clay films; firm when moist, slightly sticky and slightly plastic when wet; pH 4.7; gradual, wavy lower boundary. 10 to 17 inches thick.
B_{x2} - 37 to 49 inches, light yellowish-brown (10YR 6/4) loam; 5 percent rounded gravel; many, medium, distinct, gray (5Y 6/1) mottles; yellowish-brown (10YR 5/4) coatings; strong, coarse, prismatic structure; very thick; discontinuous clay films; firm when moist, slightly sticky and slightly plastic when wet; pH 4.6; gradual, wavy lower boundary. 9 to 15 inches thick.
C - 49 to 55 inches+, yellowish-red (5YR 5/6) fine sandy loam; 10 percent rounded gravel; many, medium, distinct, pale-brown (10YR 6/3) mottles; weak, medium, platy structure; friable when moist, slightly sticky and slightly plastic when wet; pH 4.6.

The surface layer ranges from silt loam to heavy silt loam or loam in texture and from very dark grayish brown to grayish brown in color. The subsoil ranges from loam through gravelly clay loam to silty clay loam in texture and from yellowish brown to yellowish red in color. The depth to the fragipan ranges from 18 to 36 inches. The thickness of the pan ranges from 12 to 36 inches. In many places the soil is underlain by a mixture of stratified sand and gravel and fine-textured material. Bedrock is at a depth of 4 to 10 feet.

As evidenced by the wealth of descriptive material in the previous paragraphs, the Monongahela series seems to be quite

adequately described. In other words, the range of characteristics for the series has been well defined. However, when we consider the descriptions of the actual mapping units carrying the series name another condition exists:

> Monongahela silt loam, 3 to 8 percent slopes, moderately eroded (M_oB_2). - This soil has the profile described as typical for the series. The present plow layer is generally a mixture of what is left of the original surface layer and material from the subsoil.
>
> This soil is suitable for general farm crops. Erosion is the major hazard (Capability unit IIe-4; woodland group 5).

When this mapping unit description is compared to the excellent treatment of those in the Clinton County, Michigan, report, written some 26 years earlier, the concept of progress is replaced by one of retrogression.

The soil map accompanying this report is published at a scale of 1:15,840 or 4 inches = 1 mile. Detail varies with complexity of soil pattern and topography from about 10 delineations to over 110 delineations per square mile, with the average probably about 80 to 90.

Lying just north-northeast of Westmoreland County, and sharing a common boundary, is Indiana County, Pennsylvania. The county seat, Indiana, is located 45 miles east-northeast of Pittsburg. This county is large at 831 square miles, but not as large as Westmoreland. The population has declined from 90,000 in 1920 to about 75,000 in 1960. Apparently this reflects a reduction in coal mining operations. Nevertheless, a county lying within a 100 mile radius of a major metropolitan area cannot ignore the influence of non-agricultural demands on land use. Therefore, a soil survey of such an area should be made with the strong likelihood of urban usage in mind.

The Soil Survey of Indiana County, Pennsylvania (Weaver et al., adequately described. In other words, the range of characteristics for the series has been well defined. However, when we consider the description of the [illegible] carrying the [illegible] name [illegible]

1968), while pre-dating the Westmoreland County survey by nearly a year, has a slightly modified format which seems to reflect subsequent thinking. One feature included is three-dimensional block diagrams showing relationships between soils and landscape positions in important soil associations. Block diagrams had appeared before, in the 1963 Soil Survey of Bath County, Kentucky (Weisenberger, Blevins, and Hersh, 1963), for example. However, their use was not widespread before 1960.

A new section in the Indiana County soil survey report is entitled "Selected Nonfarm Uses of the Soils," and is quoted, in part, in the following passage:

> In recent years, a significant part of the county's population has shifted from cities to suburban or rural areas. Many houses have been build along major highways, and much former farmland has been converted to housing developments, especially near Indiana, Homer City, Blairsville, and Saltsburg. This new housing, for the most part, depends on wells for water supply and on septic tanks for sewage disposal.
>
> Features that affect the use of soils for purposes other than farming include depth to bedrock, internal drainage, depth to watertable, susceptibility to flooding, stability, stoniness, and degree of slope. This soil survey can be used in planning future housing and in solving problems that arise as use of the land changes, but it does not eliminate the need for investigation at the site of a planned development.
>
> In this section the soils of the county have been placed in community development groups on the basis of the soil features that affect nonfarm uses. The soils in each group are referred to by series name, but this does not mean that all the soils of a series are in the particular group. Refer to the Guide to Mapping Units at the back of this report for the names of the mapping units and the community development group in which each has been placed. In table 7, the limitations of the soils for specific nonfarm uses are rated slight, moderate, or severe, and the chief limiting properties are given. Location, in relation to established centers or transportation lines, and other economic factors are important and will affect the selection of a development site. These factors, however, were not considered in estimating the degrees of limitation shown in table 7.

In addition there is a rather comprehensive treatment of the geology of the county in the section entitled "Relief, Drainage, and Geology." Many of the earlier reports contained similar sections, but for some reason geology is scarcely mentioned in the Westmoreland County report. The Indiana County report discusses the relationship between geologic formations and specific soil series, as shown in the following passage:

> Allegheny Formation - This formation averages 300 feet in thickness and is the second most extensively exposed formation in the county. The top of the Allegheny is marked by Upper Freeport coal; its base is the massive Homewood sandstone. The Allegheny formation is most extensive in the northeastern part of the county and on the Chestnut Ridge but occurs near Blacklick Creek, at the headwaters of Little Yellow Creek, and near McIntyre and Jacksonville. It includes most of the productive coals, the Freeport and Kittanning, in the county. Between the coal beds are strata of gray-clay shales, olive-drab shale, shaly to massive sandstone, and thin beds of limestone. The Gilpin, Weikert, Wharton, and Cavode soils formed in the upper part of the Allegheny formation; and the Dekalb, Clymer, and Cookport soils formed in the lower part.

The soil maps in this report vary in detail from about 15 to more than 110 delineations per square mile. This variation is due to a number of factors, one being, of course, the variation in soil pattern and complexity. There are other and perhaps more important reasons for variations in detail and style of mapping. A note at the beginning of the report states that major field work for this soil survey was done in the period 1935-1961. This is a period of 26 years from the date of the first mapping to the last; a period in which two major classification schemes and an important modification of one of them had been developed. It was a period during which our nation changed from a mixed agrarian - industrial society to one predominantly urban in character.

During this period, 18 soil surveyors participated in classifying

and mapping the soils of this county. With so many individuals occupied in a venture, over so long a period, under so many different schemes of classification, and variations of leadership, a heterogeneity of mapping should be the rule rather than the exception. It would be surprising if anyone could take this mass of accumulated data and make from it anything remotely comparable in quality to the product one would expect from a small, coherent party conducting a progressive soil survey. Rather than call a publication such as this a soil survey, perhaps it would be better to call it a compilation of soil survey data for the quarter-century from 1935-1961.

The purpose of this previous discussion has been to review the progress of soil survey in the United States from its inception until the present time. By using examples from about 18 selected soil surveys, an attempt was made to trace the development of the soil survey as well as the evolution of soil classification. The soil survey program in the United States is a cooperative effort between the United States Department of Agriculture and other interested federal and state agencies, particularly the Land-Grant Colleges and Universities. In most cases, whenever a soil survey and report have been examined, one may assume that others throughout the United States of the same era will be similar, differing only slightly because of individual styles of writing, areas of interest, and problems unique to the particular survey areas.

As was pointed out previously, in the first three decades of the twentieth century, the format of the Iowa and Illinois surveys differed from the national (federal) standard. For a time, Illinois was not using the national system of series names and correlation.

Long after they returned to the national system, they published their own survey reports and maps in an individualistic format. These reports, such as <u>McHenry County [Illinois] Soils</u> (Ray and Wascher, 1965), which were being published by the University of Illinois as late as the 1960's, differ from soil survey reports published by the U.S.D.A., Soil Conservation Service chiefly in the inclusion of small drawings of each soil profile along with the soil type description. In addition, the soil map is published on a plain paper base instead of an aerial photographic base. In the McHenry County survey, the soil types are described in considerable detail while only minor consideration is given to mapping unit composition. This publication does not give specific management suggestions. These are given in a separate University of Illinois publication entitled "Soil Management Guide, McHenry County, Illinois, Your Personal Guide to Better Understand and Manage Your Soils," which is planned for frequent revision as new management facts become known and farming techniques are developed.

G. DEFINITION OF THE "URBAN SOIL SURVEY"

Defining character of the population of the county being surveyed is sometimes difficult. Such factors as distance from a metropolitan center, size of the center, nature of linking highways, county population and recent growth, and shifts in basic occupations all play a part in such definitions. Blumenfeld (1965, p. 41) defines a metropolis as "a concentration of at least 500,000 people living within an area in which the traveling time from the outskirts to the center is no more than about 40 minutes." Using interstate highway speed limits and interchange facilities as criteria, this

should translate to a radius of 45 to 50 miles. If one considers employees commuting to peripheral light industry, the radius of urbanization might be extended another 40 miles. This would encompass a tier approximately two counties wide encircling the center of the metropolis.

Using a different approach, when significant financial aid for obtaining a soil survey becomes available through planning units of a metropolitan or county governing body, the county or area is moving toward urbanization (Obenshain, 1966, p. 175).

In trying to define an urban soil survey one might attempt an indirect approach. If by defining a non-urban soil survey one learns to recognize an urban soil survey by contrast, the purpose has been achieved. Apparently the <u>Soil Survey of Carroll County, Virginia</u> (Thomas et al., 1967), is a non-urban survey. Field work for this survey was in progress during the period of 1957-62 and it was issued in 1967. This county has an area of 496 square miles and lies mostly in the Blue Ridge Mountains along the North Carolina line in Southwestern Virginia. The county seat, Hillsville, lies about 55 miles from both Roanoke, Virginia, and Winston-Salem, North Carolina. In 1960 the population was 23,178. The introduction of the report contains the following statement:

> The county is mainly agricultural. More than half the acreage in farms is used as woodland, and about 60 percent of the acreage cleared is used as pasture. Most farm income is from livestock, mainly beef and dairy cattle. A few sheep, hogs, and poultry are also raised. Well-suited crops include hay, which is the crop most extensively grown, and pasture and orchards. Apples are an important crop.
>
> The chief industries are lumbering, furniture manufacturing, and textile manufacturing.

Certainly this county appears to be non-urban, or at least, with a should terminate in a radius of 40 to 50 miles. If the consolidated employees commuting to peripheral light industry, the radius of urbanization might be extended another 40 miles. This would [illegible] employment population of only 47 per square mile, or 13.6 acres per person, the population pressure is not yet great.

By studying the format of the Carroll County soil survey report one can find no significant differences compared to recent "urban soil surveys." It has a section on engineering uses of the soils as well as one on soil interpretations for non-farm uses. The section on non-farm uses contains the following statement:

> Although the detailed soil map and the table serve as guides for evaluating most soils, a detailed investigation at the site of the proposed construction is needed because as much as 15% of an area designated as a specific soil on the map may consist of areas of other soils too small to be shown on the published map. By comparing the soil description with the result of investigations at the site, the presence of an included soil can usually be determined.

Apparently written directives and memoranda to define agricultural and non-agricultural soil surveys, and to establish guidelines for separate treatment of such items of major importance as mapping scale, intensity, sampling, analyses, and descriptions do not exist at the present time. At least there seems to be no evidence of their existence reflected in published soil survey reports of counties having a dense population, or which are experiencing a rapid population growth as compared to counties having a relatively low population and which are definitely rural in character. If this is true, if there is no real difference between these surveys, then we should cease referring to "urban soil surveys" and "agricultural soil surveys," for they are all the same.

population of only 47 per square mile, or 13.6 acres per person, the population pressure is not yet great.

By studying the format of the Central Shale soil survey report ... compared to

III. DESCRIPTION OF THE STUDY AREAS

Several field studies were carried out during the course of this research.

A field study in Clinton County was designed to measure homogeneity of mapping units in the modern urban soil survey of the Tri-County Area. Townships studied were Bath, DeWitt, Eagle, Ovid, Riley, and Victor, which provided a good sampling of the soils of the southern and eastern portions of the county. Using the old soil survey as a guide, areas were selected in which large delineations of a certain series had been mapped. Some dozen of the most extensive mapping units were checked in this manner.

According to the surficial geology map, most of these areas were in either ground moraine or moraine (sandy in this instance). A few were located in areas classified as spillways.

Two studies in intensive mapping were made in the western half of Section 31, Meridian Township in Ingham County, Michigan. Section 31, which is located in the northwestern corner of Ingham County near the center of the Tri-County Soil Survey Area, was chosen for the following reasons:

1. The property belonged to Michigan State University which enabled a number of people to spend an inordinate amount of time, apparently doing nothing worthwhile, without arousing undue suspicion.
2. It contained a wide range of soil and topographic conditions, representative of approximately half the till plain in the Tri-County Area.
3. Not only had it been mapped in 1933, during the original Ingham

County soil survey, but it had been mapped in detail by the U.S.D.A., Soil Conservation Service in 1950 to be used as a planning base for intensive agricultural research.

4. It was less than three miles from Michigan State University, which greatly facilitated transportation.

The northwestern 1/4 of this section was used to study the effect of surveyor bias, and, to a lesser extent, mapping scale and speed of survey on number, size, and homogeneity of delineations.

The southwestern 1/4 of this section was used in a more intensive study of the effect of mapping scale on the number, size, and homogenetity of delineations.

According to the Surficial Geology Map of Michigan's Lower Peninsula, Section 31 of Meridian Township is formed of ground moraine (till plain) (Martin, 1955). Ground moraine is defined as "drift that is widely distributed, ordinarily relatively thin, consisting chiefly of till, and having a gently irregular initial surface form..." (Longwell et al., 1941, p. 140). Although defined as "ordinarily relatively thin," studies in Central Ohio show an average thickness of drift to be about 96 feet, with depths of about 50 feet over buried uplands and 200 feet over buried valleys (Thornbury, 1965, p. 218).

In Section 17, Riley Township, Clinton County, Michigan, a study was made to compare variations among descriptions of the same two profiles by several soil surveyors. The site location was a borrow pit near the lower end of a ridge which merged into a nearly level flat. Parent material consisted of stratified loams and sands with soils varying from well drained to somewhat-poorly drained.

A final field study was made in Section 31, Meridian Township, Ingham County. In this study three operators working in a delineation of about 4 acres mapped as Conover loam selected modal and marginal pedons of this soil type. These pedons were described and compared as a measure of uniformity of concept among soil surveyors.

IV. METHODS OF INVESTIGATION

A fundamental assumption that man desires more - not less - factual information, more - not less - accuracy in describing natural phenomena, and more - not less - detail in soil surveys is made in this study. Another fundamental assumption is that three factors work to limit the accuracy of a soil survey:

1. The complexity of the survey area.
2. The administrative restrictions imposed upon the surveyors.
3. The human limits of the surveyors themselves.

Each of these factors is given some consideration in the course of these investigations.

A. The best analysis of the adequacy of a soil map is the evaluation of the map itself. Although this may not permit the observer to trace the cause of error, it will give him the best approximation of the magnitude of this error. For this reason 12 mapping units in Clinton County were examined in detail. All observations were made at 250 foot intervals along transects drawn parallel to section lines at 500 foot intervals. At every observation point falling within a delineation, with the exception of points falling on such things as buildings or bodies of water, a boring was made and the soil profile recorded. All data, including delineation lines crossing transects, were recorded on acetate film overlying the original field sheets. Field sheets were selected to give a broad coverage of surficial geological formations, soil mapping associations and units, and work of various soil surveyors. Hopefully, the analysis of these data would give an approximation of mapping unit content throughout the survey area.

B. The next approach was to determine the amount of variation among

the soil maps of a number of individuals who had surveyed the same area. For this study the NW 1/4 of Section 31, Meridian Township, Ingham County, Michigan,was selected. For this section the following information was already available:

1. The soil maps and descriptive legend of the 1933 soil survey of Ingham County. While this survey was made on a 1 inch = 1 mile mapping scale and is less detailed than modern soil surveys, knowledge of the homogeneity of the mapping units with respect to the way in which they were described would serve as a basis of comparison for judging later and more detailed soil surveys.
2. A detailed soil map made in 1952 by the U.S.D.A., Soil Conservation Service of the Michigan State University farm property for research purposes. Since this map was made on a scale of 1 inch = 660 feet, is more detailed than most of the mapping of this era, and was made as a basis for potential research plot work, we may assume the units shown were considered homogeneous when they were delineated.

With this information as a background, 5 individuals experienced in working on the Tri-County soil survey mapped this quarter section in 1967. They were instructed to operate under the normal constraints by the Tri-County soil survey in regard to detail shown, time required in mapping, and number of soil observations made. They were asked to record each soil observation, locating each auger hole on the map and identifying the soil observed, and then label the composite as the mapping unit within the delineation.

To obtain an objective analysis of the area, the entire quarter

section was gridded with transects at 400 foot intervals, and observations were made by the author at 200 foot intervals along each transect. In three rather complicated soil areas observations were made at greater frequency. Each observation was logged, with depth and texture of each horizon recorded along with slope gradient and aspect. When pertinent, other morphological features such as horizon identification, Munsell matrix and mottling colors, reaction, and special features were recorded also. While these precautions did not eliminate personal bias entirely, they should have reduced it far below the normal operational level accompanying field evaluation of the soil profiles and mapping delineations.

C. To determine the relationship between mapping scale and mapping precision, a study was made on 4 adjacent 40-acre tracts, mapping each one at a different scale. These scales were 1 inch = 1320, 660, 330, and 200 feet. The author served as surveyor in this study, and every effort was made to permit mapping scale to be the only independent variable. In other words, a conscious effort was exerted to make no additional observations and take no more time in making delineations as mapping scale increased. More observations were made only when the survey area became more complex or increased scale called attention to previously unrecognized and unidentified soil areas. To serve as a measure of mapping precision, this quarter section was gridded with transects at 500 foot intervals, and observations were made by the author at 250 foot intervals along each transect.

D. One of the primary requisites in soil classification and mapping is the identification of the pedon. A necessity for such

identification is the ability to correctly describe morphological features. The descriptions of the morphological characteristics of the separate layers of a pedon are known as a profile description. Two exposures were selected for this study - a soil profile some 8 feet deep and 20 feet long and another profile of about the same length but with a depth of only 5 feet, the lower half being a natural soil formation and the upper, disturbed overburden. Six individuals were asked to describe these exposures. By comparing their evaluation of such items as matrix color and structure, their precision of observation could be evaluated. By comparing their horizon identifications and sequence nomenclature, the accuracy of their judgment could be approximated. This study was located in the NE 1/4 of the NE 1/4 of Section 17, Riley Township, Clinton County, Michigan.

E. In soil classification and in the use of soil for a particular purpose, perhaps the single most important morphological characteristic is texture. The soil surveyor continually is pressing soil material between his fingers, automatically evaluating the texture of each layer of the soil profile as he drills his auger into the ground to examine a pedon. A change in the texture of the A horizon usually signals a change in soil type, while a textural change in the B horizon may indicate a change in soil series. Because this evaluation of texture is so fundamental to soil classification, the skill of the soil surveyor in estimating soil texture is of paramount importance.

In order to measure their skill in estimating soil texture, a set of 20 textural samples of Michigan soils was offered as a

laboratory examination to 10 soil surveyors whose field experience varied from 1 to 25 years. These operators were asked to examine previously-moistened samples and estimate the textural class in which they would fall.

F. To test the conceptual differences among individuals as to the limits of the range of characteristics allowable in the somewhat-poorly drained soil type, Conover loam, three experienced soil surveyors selected sites typifying "high," "low," and "modal" Conover loam profiles. In essence, this is asking an individual to erect a fence around a taxonomic unit with respect to its position in the toposequence. When an individual selects what he considers a "best-drained Conover," he is saying that, given one significant increment of improvement in natural drainage, the soil would no longer be Conover, but Celina loam, Conover's moderately-well drained counterpart. By the same token, one increment below "most poorly drained Conover" would force the soil to be classified as Brookston loam, the poorly drained member of the Miami catena. An ability to skillfully select high, modal, and low examples of the Conover series would indicate a soil surveyor's proficiency in distinguishing among the three lower members of the Miami catena.

G. In the use of soils for urban development the most important set of characteristics are the physical properties of the soils. Therefore, 5 soil profiles were sampled, described, and analyzed for particle size distribution, swelling potential, bulk density, and moisture characteristics. These soils are widely distributed, comprising a large portion of the Tri-County Soil Survey Area. They cover a wide textural range and can be used as bases for interpolation

of characteristics for most soils in the area. In addition, these data should indicate the magnitude of contrast in behavior of inclusions in a mapping unit as compared to the behavior of the predominant individual in the unit. For example, if a mapping unit is predominately Miami loam but contains inclusions of Metea loamy sand, then the behavior of these inclusions, which have an "upper story," or capping, of loamy sand varying in thickness from 18 to 42 inches, would approach that of Chelsea loamy sand, one of the soils analyzed.

V. RESULTS AND DISCUSSION

A. ANALYSIS OF MAPPING UNITS

In the process of critical evaluation of urban soil surveys, the single most important criterion of their adequacy is the validity of the mapping units contained therein. In other words, do the areas enclosed by delineation lines contain what their descriptions say is present? If they do, then all is well and good; if they do not, then the problem is to identify and measure their components and formulate more accurate definitions, or possibly readjust the delineations to improve their validity. To this task the first part of this work was dedicated.

The mapping unit is that unit identified on the soil map by an alphabetical or numerical symbol. It is composed of all the delineations identified by that symbol within the survey area. The name of the mapping unit is the name of a taxon, a phase of a taxon, or some combination of such entities.

A soil taxon is a unit of classification and is conceptual rather than geographical. A taxon includes the central concept of a soil class and associated properties such as the kind and arrangement of horizons and their texture, structure, color, and consistence. Each taxon or phase of a taxon has a range within which these parameters are allowed to vary. When a soil profile is examined, it is compared to the concept of one or more taxonomic units. The mapping unit represents an area, but the taxonomic unit normally represents only a part of that area.

The Soil Survey Manual defines a mapping unit in the following manner (Soil Survey Staff, 1951, p. 277):

> A soil mapping unit that bears the name of a taxonomic unit consists of this defined taxonomic unit and sometimes also small inclusions of other soils that must be included because of the limitations imposed by the scale of mapping and the number of points that can be examined. In other words, any single soil name stands for a specially defined unit in the taxonomic system of classification; but that same name, applied to a mapping unit, stands for that defined taxonomic unit plus a small proportion of other units, up to about 15 percent, that cannot be excluded in practical cartography.

The preceding definition will be reconsidered at the close of this first section in light of the results of this study and subsequent definitions.

Mapping units analyzed in this study were located in Clinton County, Michigan. Selection of field sheets containing these units was motivated by an attempt to examine the average composition of the units as mapped in the survey area. For this reason different soil landscape areas and the work of different soil surveyors were included. This should have attenuated the effects of individual biases and variations caused by differences in landscape position.

Once the transects were drawn and observation points were ticked off on these transects, an attempt was made to examine the soil and record observations at each observation point within the mapping unit. Thus, if a unit such as 4505/C2 were being analyzed and a transect passed through 5 delineations of 4505/C2 on the field sheet, then the observation points falling on the portions of this transect lying within these delineations would be examined and recorded. This is illustrated in Fig. 1.

Previous work[1] had indicated that 50 or more observations on

---

[1] Lyle H. Linsemier. 1968. Use of the point-intersept transect in Michigan soil surveys. M.S. Thesis. Michigan State University, East Lansing. 94 p.

a soil mapping unit that bears the name of a taxonomic unit consists of this defined taxonomic unit and associated with small inclusions of other soils that must be included because of the limitations imposed by the scale of mapping and the number of points that can be examined. [illegible] single soil [illegible] specially defined [illegible]

5 or more transects were sufficient to give a reasonably valid picture of the composition of a mapping unit. In this study 12 mapping units were examined to this extent.

In this as well as some of the other studies, the work of others was evaluated by the author. Questions regarding the author's judgement and objectivity are natural and [illegible] to these studies. At the time these studies were made, the [illegible] more than 10 years [illegible] chief. He had [illegible] two years [illegible]

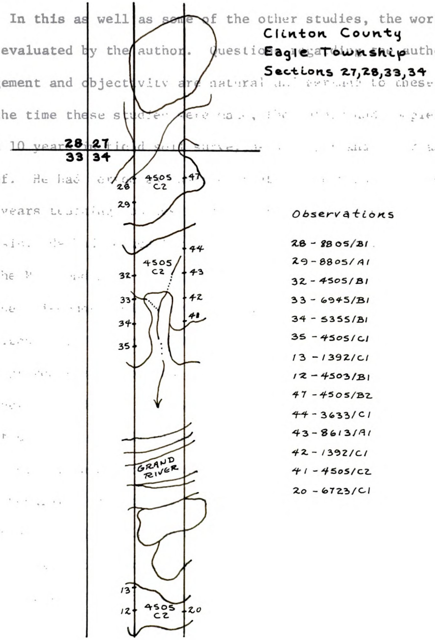
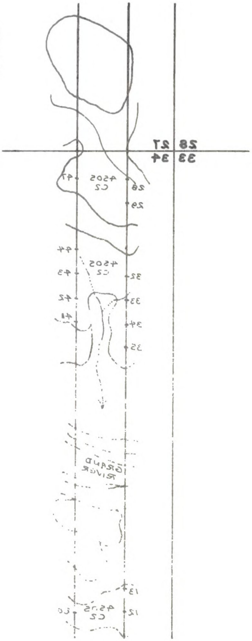


Fig. 1. Sample transect.

Clinton County
Eagle Township
Sections 27,28,33,34



Observations

28 - 8805/B1
29 - 8805/A1
32 - 4505/B1
33 - 6945/B1
34 - 5355/B1
35 - 4505/C1
13 - 1392/C
12 - 4503/B1
47 - 4505/B2
44 - 3433/C1
43 - 8613/A1
42 - 1392/C1
41 - 4505/C2
26 - 6723/C1

Fig. 1. Sample Transect.

5 or more transects were sufficient to give a reasonably valid picture of the composition of a mapping unit. In this study 12 mapping units were examined to this extent.

In this as well as some of the other studies, the work of others was evaluated by the author. Questions regarding the author's judgement and objectivity are natural and germane to these studies. At the time these studies were made, the author had completed more than 10 years in field soil survey as a mapper and later as a party chief. He had served as instructor at the University of Kentucky for two years teaching courses in soil morphology, classification, and genesis. He had served for 6 months as interpretive soil scientist in the Richmond Area in Virginia. He had also served for 9 months in the Tri-County soil survey as mapper and supervisor of the Michigan State University soil survey trainees. Of course none of this proves the author was qualified to judge the work of another. However, he had been exposed to some excellent opportunities to study the techniques of soil classification and mapping, particularly as they apply to non-agricultural use of soil survey information.

Regarding objectivity, soil classification tends to suffer from compounded subjectivity no matter how hard we try to purge it from the classification system and evaluation processes. The evaluation of soil color, one of the most easily measured soil parameters when standard color charts are used, is still subjective to the degree in which people vary from strong color vision through many degrees of "color weakness" to complete color blindness. Although defective color vision is estimated to affect only about 4% of the male population (Ruch, 1963, p. 245), it remains a factor in estimating

the soil color parameter. In the evaluation of the work of others, the author of this dissertation does not claim complete objectivity: using the best tools at his disposal he did try to keep subjectivity to a minimum.

Normally when a soil surveyor makes a taxonomic identification, he is functioning to a significant extent in the subconscious. He selects his sampling position without giving it a great deal of conscious attention: he will go automatically to the spot where experience has indicated he will find the best expression of the morphological characteristics he considers typical of the land form he intends to enclose with a delineation line. In the process of examining the soil's characteristics, he bores the hole rapidly, cleaning the auger with as much speed as possible and letting the soil trickle through his fingers, pausing occasionally to give what appears to be a superficial evaluation of color, mottling, texture, and other characteristics. In this respect he is like the mineralogist described by Berry and Mason (1959, p. 251):

> To him [the beginning student] the facility with which an experienced mineralogist can often put a name to an apparently nondescript specimen merely on sight, aided perhaps by hefting or by scratching with a pocket knife, is an enviable and apparently unattainable one. Here the role of familiarity must be emphasized - an experienced mineralogist instinctively sums up the characters of an unknown specimen and compares them with his memory picture of the innumerable specimens he has previously identified. The best analogy is the recognition of a person we have seen many times by the sum total of features, dress, gait, voice, and other characteristics.

For the purpose of this work, the author decided the technique just described was not good enough. While it is usually valid, it is often biased, always subjective, and lacks the quantitativeness necessary for a standard of comparison.

Part of the subjectivity can be eliminated by using a grid to locate sampling sites, and this was done. In addition, as the soil at each site was examined, it was "laid out," a technique by which the soil profile is reconstructed on the ground surface beside the hole, using material extracted by the bucket (orchard) auger, a device that removes 3 inch, slightly disturbed soil cores from the ground. Here, at least, the soil profile could be examined after the exertion of boring; and the morphological characteristics of the profile could be studied in relative leisure.

Deviations from the range of characteristics considered "normal" were noted on an acetate sheet overlying the field sheet, as well as examples in which the "perfect norm" was expressed. Proximity of sampling site to delineation lines, natural drainage-ways, and other modifying features was noted whenever they might influence soil properties. Marginal soils were indicated as such, and reasons for placement were noted. Therefore, upon completion, the author had considerable information concerning the make-up of the various mapping units, as well as a good basis for comparison of each observation to the taxonomic concept of the individual for which the mapping unit was named.

A survey area of the size of the one studied here normally has a legend of 50 to 100 or more mapping units. Most of the units will be of small total acreage, with the major portion of the survey area being partitioned among 10 to 20 mapping units. For this reason, 12 of the more extensive and important mapping units in Clinton County were chosen for analysis. The units selected are listed in Table 1. The approximate extent of these units is given in

Table 1. Analyzed Clinton County mapping units and their classification.

Mapping unit	Series	Soil Type	Soil Phase	Management[1] group	Texture: Parent material	Texture: Surface soil	Soil drainage	7th Approximation classification
2342/B1	Spinks	Spinks ls[2]	Spinks ls[2] 2-6% slopes	4a	s & ls[2]	ls[2]	well	Psammentic Hapludalfs; sandy, mixed, mesic
2552/A1	Boyer	Boyer ls	Boyer ls 0-2% slopes	4a	upper - ls to sl lower - s & gr	ls	well	Typic Hapludalfs; coarse-loamy, mixed, mesic
3443/A1	Fox	Fox sl	Fox sl 0-2% slopes	3a	upper - l to sl lower - s & gr	sl	well	Typic Hapludalfs; fine-loamy over sandy or sandy skeletal, mixed, mesic
4505/B1	Miami	Miami l	Miami l 2-6% slopes	2.5a	l	l	well	Typic Hapludalfs; fine-loamy, mixed, mesic
4505/C2	Miami	Miami l	Miami l 6-12% slopes moderately eroded	2.5a	l	l	well	Typic Hapludalfs; fine-loamy, mixed mesic

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Table 1. (Cont.)

Mapping unit	Soil: Series	Soil: Type	Soil: Phase	Management group	Texture: Parent material	Texture: Surface soil	Soil drainage	7th Approximation classification
5355/B1	Celina[3]	Celina 1	Celina 1 2-6% slopes	2.5a	1	1	moderately-well	Typic Hapludalfs; fine-loamy, mixed, mesic
6455/A1	Conover	Conover 1	Conover 1 0-2% slopes	2.5b	1	1	somewhat-poorly	Udollic Ochraqualfs; fine-loamy, mixed, mesic
6455/B1	Conover	Conover 1	Conover 1 2-6% slopes	2.5b	1	1	somewhat-poorly	Udollic Ochraqualfs; fine-loamy, mixed, mesic
8745/A1	Sebewa	Sebewa 1	Sebewa 1 0-2% slopes	3c	upper - 1 lower - gr & s	1	poorly	Typic Argiaquolls; fine-loamy over sandy or sandy-skeletal, mixed, mesic
8805/A1	Brookston	Brookston 1	Brookston 1 0-2% slopes	2.5c	1	1	very-poorly	Typic Argiaquolls; fine-loamy, mixed, mesic

Table 1. (Cont.)

Mapping unit	Series	Soil Type	Soil Phase	Management group	Texture Parent material	Texture Surface soil	Soil drainage	7th Approximation classification
8815/A1	Pewamo	Pewamo 1	Pewamo 1 0-2% slopes	1.5c	cl	cl	poorly	Typic Argiaquolls; fine, mixed illitic, mesic
8848/A1	Lenawee	Lenawee sicl	Lenawee sicl 0-2% slopes	1.0c	sic	sicl	poorly	Mollic Haplaquepts; fine, illitic, nonacid, mesic

[1]Management groupings of Michigan soils are given in Michigan State University Extension Bulletin E-550, Fertilizer Recommendations, February, 1970.

[2]Abbreviations of soil textural classes are given in the Appendix.

[3]The Celina unit was subsequently renamed Miami, mottled subsoil phase.

Table 2.

An example of the summation of observations for a mapping unit is given in Table 3. This is the analysis of unit 6455/B1 which is Conover loam, 2 to 6% slopes, one of the most extensive mapping units in the Tri-County Survey Area. A total of 84 observations were recorded on 9 field sheets from 5 townships in Clinton County. As mentioned previously, this represents the work of several individuals mapping on land forms of considerable areal extent and dispersion, which should give a fairly good composite of the mapping unit.

The analysis of this unit indicated that 26.2% of the observations agreed with the mapping unit at the phase of series level (i.e. the same soil type, slope, and erosion), 32.2% at the series level, and 76.2% at the catena[1] level (i.e. soils differing only in surface texture, topography, and natural drainage). The distribution of observations in the 6455/B1 unit which fall in the Miami catena are plotted in Fig. 2.

The distribution shown in Fig. 2 suggests a paradox worthy of consideration. Since Conover is a somewhat-poorly drained soil, one would expect a curve skewed toward this part of the toposequence. The dip of the Celina bar and subsequent rise of the Miami bar indicates either an error in the sampling technique, an inadequate description and naming of the mapping unit, or a fundamental weakness in the Celina concept. The possibility of an untenable Celina concept will be discussed in greater detail later in this section.

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[1]Catena is used synonomously with toposequence throughout this dissertation.

Table 2. Approximate acreage[1] of the analyzed mapping units.

Mapping unit	Mapping unit name	1936 soil survey equivalent	Approximate acreage	% of county land area
2342/B1	Spinks ls[2]	Bellefontaine ls	1,500	.4
2552/A1	Boyer sl	1/2 Oshtemo sl	3,000	.8
3443/A1	Fox sl	Fox sl	11,000	3.0
4505/B1	Miami l	Miami l & 2/3 Miami sil	75,000	21.0
4505/C2	Miami l, 6-12% slopes moderately eroded	2/3 Miami l, rolling phase	14,000	4.0
5355/B1	Celina l[3]	Included in Miami & Conover		
6455/A1 /B1	Conover l	Conover l & 2/3 Conover sil	75,000	21.0
8745/A1	Sebewa l	Included in Brookston		
8805/A1	Brookston l	Brookston l	16,500	4.5
8815/A1	Pewamo cl	Brookston cl	18,000	4.9
8848/A1	Lenawee sicl			
Totals			214,000	59.6

[1]Based on the 1936 Soil Survey of Clinton County, Michigan.

[2]Abbreviations of soil textural classes are given in the Appendix.

[3]The Celina unit was subsequently renamed Miami, mottled subsoil phase.

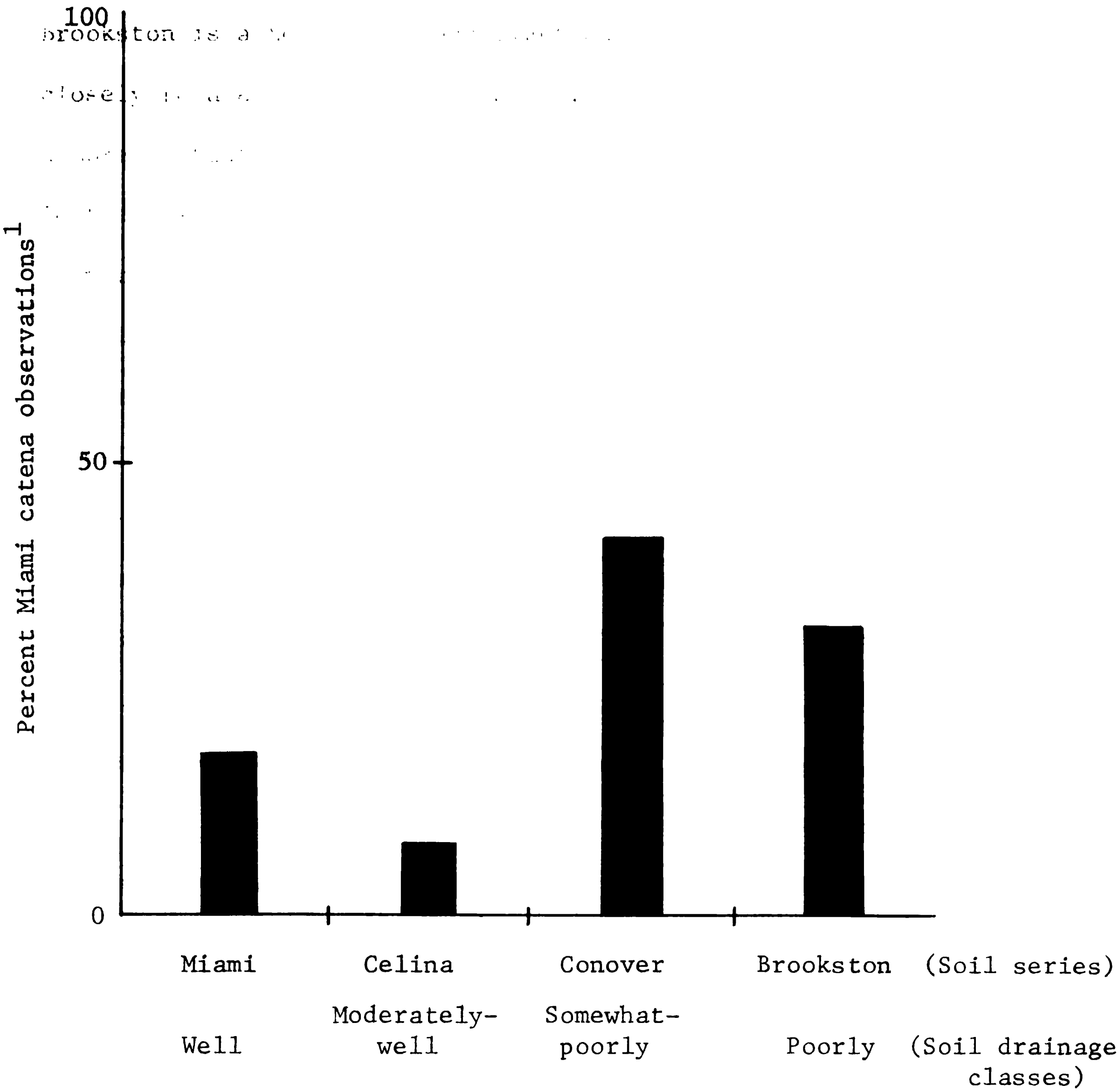
Table 3. Mapping unit composition of Conover loam, 2-6% slopes.

Township	Aerial photograph	6455/B1	6455/B2	6455/A1	4505/B1	4503/B1	4503/B2	5355/B1	5355/B2	8805/A1	8805/B1	8805/C1	2183/B1	3493/B1
		Taxonomic observations												
Victor	BDJ-1EE-13	10	1	1	-	3	3	3	-	5	3	-	-	-
Ovid	BDJ-1EE-73	-	-	-	-	-	-	-	-	1	-	-	1	-
Ovid	BDJ-1EE-75	3	-	-	1	-	-	-	-	3	-	-	-	-
DeWitt	BDJ-1EE-105	1	-	-	1	-	-	-	-	-	-	-	-	1
Riley	BDJ-2EE-36	7	-	2	-	3	-	-	1	-	1	-	-	-
Riley	BDJ-2EE-69	-	-	1	-	-	-	-	-	1	-	-	-	-
Riley	BDJ-2EE-71	-	-	-	-	-	-	-	-	-	-	-	-	-
Riley	BDJ-2EE-73	-	-	-	-	-	-	-	-	-	-	-	-	-
Eagle	BDJ-2EE-130 (East)	-	-	-	-	-	-	-	-	1	-	-	-	-
Eagle	BDJ-2EE-130 (West)	1	-	-	1	-	-	-	1	2	2	1	-	-
	Total	22	1	4	3	6	3	3	2	13	6	1	1	1
	Percentage	26.2	1.2	4.8	3.6	7.1	3.6	3.6	2.4	15.5	7.1	1.2	1.2	1.2
	Percentage[1]	26.2		32.2								76.2		
		Phase		Series								Catena		

[1]Cumulative through catena.

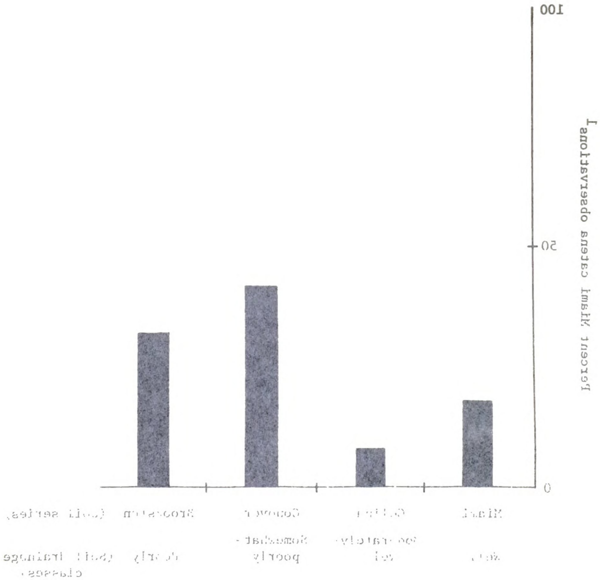
Table 3. (Cont.)

Township	Aerial photograph	3493/C1	6303/A1	6405/B1	6463/B1	6893/A1	6945/B1	7592/B1	7613/B1	8613/A1	8613/B1	8815/A1	8817/A1	8848/A1	Total
		Taxonomic observations													
Victor	BDJ-1EE-13	-	-	-	1	-	-	1	-	1	1	-	-	-	33
Ovid	BDJ-1EE-73	-	-	-	-	3	-	-	-	-	-	-	-	-	5
Ovid	BDJ-1EE-75	-	-	-	-	-	-	-	-	-	-	-	-	-	7
DeWitt	BDJ-1EE-105	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Riley	BDJ-2EE-36	-	-	1	-	-	-	-	1	-	-	-	1	-	17
Riley	BDJ-2EE-69	-	1	-	-	-	-	-	-	-	-	-	-	-	3
Riley	BDJ-2EE-71	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Riley	BDJ-2EE-73	-	-	-	-	-	1	-	-	-	-	1	-	-	2
Eagle	BDJ-2EE-130 (East)	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Eagle	BDJ-2EE-130 (West)	1	-	-	-	-	-	-	1	-	-	-	-	2	12
	Total														84
	Percentage	1.2	1.2	2.4	1.2	3.6	1.2	1.2	2.4	1.2	1.2	1.2	1.2	2.4	
	Percentage													23.8	
														Others	



[1]Adjusted to 100%.

Fig. 2. Distribution of Miami catena observations in Conover loam, 2-6% slopes.



[1]Adjusted to 100%.

Fig. 7. Distribution of Miami catena observations in Conover loam, 2-6% slope.

Since the Celina and Brookston series bracket the Conover series in the Miami catena, they may be considered marginal; and while differences are often significant (Celina and Conover are Alfisols; Brookston is a Mollisol), one might say 29.8% of the observations were closely related to Conover. The 14.3% of Miami observations represent a more distant relative and, were it not for a morphological oddity in the Miami make-up, the differences between these series would be more striking.

The official description of the Conover series (National Cooperative Soil Survey, 1967) lists the B_{22t} matrix color by the Munsell system (Soil Survey Staff, 1951, pp. 194-203) as dark yellowish brown (10YR 4/4) with mottles of brownish gray (10YR 6/2). In Miami the clay loam B_{22t} ranges in color from brown to dark brown (7.5YR 4/4) to brown to dark brown (10YR 4/3), while the overlying A_2 ranges from light yellowish brown (10YR 5/4) to brown (10YR 5/3). In the Tri-County Survey Area many Miami pedons exhibit B horizons which have been infiltrated by A_2 material from above. Perhaps alternate wetting and drying permitted swelling and shrinking of the B horizon with subsequent cracking and infiltration of A_2 material. This A_2 material occurs as ped coatings and sometimes as segregated islands within the soil matrix. In a Miami B horizon with a matrix color of dark yellowish brown (10YR 4/4) and infiltrative ped coatings and segregations of brown (10YR 5/3) material, resemblance of this infiltrative A_2 material to drainage mottles of brownish gray (10YR 6/2) is striking. In fact, the difference is often difficult or impossible to discern. This phenomenon will be discussed in greater detail in the section on testing the Conover concept.

Taxonomic observations in the Conover loam (2-6% slopes) unit, lying outside the Miami catena are listed in Table 4. These pedons, comprising 23.8% of the observations, range in texture from loamy sand to clay and in drainage from well drained to very-poorly drained.

Table 4. Taxonomic units outside the Miami catena observed in the Conover loam (2-6% slopes) unit analysis.

		Soil Drainage Class			
		Well	Moderately well	Somewhat poorly	Poorly
Texture (upper 18 inches)	Sandy	3.6%	-	9.6%	2.4%
	Loamy	-	-	3.6%	1.2%
	Clayey	-	-	-	3.6%

The results of this study of 12 Clinton County mapping units are given in Table 5. Numbers and percentage values are given for taxonomic observations only when they comprise 5% or more of the total observations. Those with values of less than 5% are combined under the heading "Other." This results in a considerable reduction of inclusions reported since the totals varied from 3 to 26, with an average of 18 per mapping unit.

Table 5. Composition of the Clinton County mapping units studied.

Mapping unit	Soil	Composition Observations	Composition Percentage
Spinks ls (2-6% slopes)	Oakville ls (2-6% slopes)	31	54
	Oshtemo ls (2-6% slopes)	4	7
	Spinks ls (2-6% slopes)	3	5
	Oakville ls, somewhat-poorly drained (0-2% slopes)	3	5
	Others	16	29
Boyer ls (0-2% slopes)	Oakville ls (2-6% slopes)	9	17
	Oshtemo ls (2-6% slopes)	8	15
	Oshtemo ls (0-2% slopes)	6	11
	Oakville ls (0-2% slopes)	6	11
	Boyer ls (0-2% slopes)	5	9
	Boyer ls (2-6% slopes)	4	7

Table 5. (Cont.)

Mapping unit	Soil	Composition: Observations	Composition: Percentage
Boyer ls (0-2% slopes) (Cont.)	Oakville ls (6-12% slopes)	3	6
	Kalamazoo sl (0-2% slopes)	3	6
	Others	10	18
Fox sl (0-2% slopes)	Oshtemo ls (2-6% slopes)	7	14
	Oshtemo sl (2-6% slopes)	7	14
	Oakville ls (2-6% slopes)	6	12
	Kalamazoo sl (0-2% slopes)	6	12
	Landes sl (0-2% slopes)	6	12
	Abscota ls (0-2% slopes)	4	8
	Others	13	28
Miami l (2-6% slopes)	Miami l (2-6% slopes)	12	24

Table 5. (Cont.)

Mapping unit	Soil	Composition Observations	Percentage
Miami 1 (2-6% slopes) (Cont.)	Miami sl (2-6% slopes)	8	16
	Owosso sl (2-6% slopes)	7	14
	Conover l (0-2% slopes)	6	12
	Hillsdale sl (2-6% slopes)	3	6
	Others	14	28
Miami 1 (6-12% slopes, moderately eroded)	Miami sl (2-6% slopes)	13	26
	Miami sl (6-12% slopes, moderately eroded)	3	6
	Oakville ls (6-12% slopes)	3	6
	Conover l (2-6% slopes)	3	6
	Corunna sl (0-2% slopes)	3	6
	Others	25	50

Table 5. (Cont.)

Mapping unit	Soil	Composition Observations	Percentage
Celina 1 (2-6% slopes)	Conover 1 (0-2% slopes)	14	19
	Miami 1 (2-6% slopes)	8	11
	Conover 1 (2-6% slopes)	6	8
	Brookston 1 (0-2% slopes)	6	8
	Celina 1 (2-6% slopes)	5	7
	Owosso sl (2-6% slopes)	5	7
	Miami sl (2-6% slopes)	4	5
	Others	26	35
Conover 1 (0-2% slopes)	Conover 1 (0-2% slopes)	17	22
	Brookston 1 (0-2% slopes)	14	18
	Conover 1 (2-6% slopes)	9	11
	Miami sl (2-6% slopes)	5	6
	Others	34	43

Table 5. (Cont.)

Mapping unit	Soil	Composition Observations	Percentage
Conover 1 (2-6% slopes)	Conover 1 (2-6% slopes)	22	26
	Brookston 1 (0-2% slopes)	13	16
	Brookston 1 (2-6% slopes)	6	7
	Miami sl (2-6% slopes)	6	7
	Others	37	44
Sebewa 1 (0-2% slopes)	Sebewa 1 (0-2% slopes)	25	40
	Gilford ls (0-2% slopes)	9	15
	Gilford sl (0-2% slopes)	4	7
	Granby ls (0-2% slopes)	4	7
	Linwood muck (0-2% slopes)	4	7
	Others	16	24

Table 5. (Cont.)

Mapping unit	Soil	Composition Observations	Percentage
Brookston 1 (0-2% slopes)	Brookston 1 (0-2% slopes)	37	53
	Pewamo 1 (0-2% slopes)	7	10
	Gilford sl (0-2% slopes)	4	6
	Others	22	31
Pewamo 1 (0-2% slopes)	Pewamo 1 (0-2% slopes)	20	38
	Pewamo cl (0-2% slopes)	11	21
	Brookston 1 (0-2% slopes)	11	21
	Gilford sl (0-2% slopes)	3	6
	Corunna sl (0-2% slopes)	3	6
	Others	5	8
Lenawee sicl (0-2% slopes)	Lenawee sicl (0-2% slopes)	39	78
	Brookston 1 (0-2% slopes)	6	12
	Gilford sl (0-2% slopes)	3	6
	Others	2	4

Of the mapping units studied here, only two represent the work of a single mapper. Likewise, those units alone were studied on only one field sheet. Fox sandy loam (0-2% slopes) is exceedingly difficult to find mapped in sizeable delineations in the Tri-County Survey Area. Therefore, since large delineations were mapped on only one field sheet, that sheet was selected for the Fox sandy loam (0-2% slopes) study. This proved to be one of the lowest in mapping unit-observation agreement of all the mapping units studied; and since no observation agreed with the name of the mapping unit, apparently it was mismapped.

On the other hand, Lenawee silty clay loam (0-2% slopes) was also found in large delineations on only one field sheet. Although of limited extent, it was purposely chosen in an attempt to select and study an apparently homogeneous mapping unit. In contrast to the Fox unit, the Lenawee unit had the highest mapping unit-observation agreement of all units studied.

Three of the twelve units studied were considered to be "two-storied" soils, or soils formed in two texturally contrasting parent materials. The remaining 9 units were "one-storied" soils, formed in uniform parent material. A diagrammatic sketch of typical profiles of the taxonomic units for which these mapping units were named is often included in Michigan soil studies. Such sketches help illustrate differences among modal profiles and summarize important morphological characteristics of the various soils. A diagrammatic sketch

of these soils is given in Fig. 3. Slanting lines between the horizons indicate variations in horizon boundary depth among profiles.

In Fig. 3 the order of units is changed in two instances: Miami loam (6-12% slopes) comes before Miami loam (2-6% slopes), and Conover loam (2-6% slopes) comes before Conover loam (0-2% slopes). This was done to provide easy comparison of Miami, Celina, and Conover profiles within the same slope range. Specifically, it was done to illustrate the problems inherent in attempting to map the Celina series. In these profiles Munsell soil colors are given for significant horizons. Since Celina is separated from Miami on the basis of having drainage mottles in the 20 - 30 inch layer and the criterion for drainage mottles is chroma 2 or less, the confusion potential is apparent. The presence of 10YR 5/3 colors in the A_2 horizon of some Miami profiles and of the calcareous 10YR 5/3 colors in the C horizon of many Miami profiles provide the basis for this confusion.

Note the similarity of the 10YR 5/2 and 10YR 5/3 color chips in Fig. 4. These colors resemble each other so closely that it is difficult to differentiate them with the color book in hand. When soil mottles are evaluated without reference to the color book, and under such modifying environments as an overcast sky, decreased light intensity of early morning and late afternoon, and shaded conditions of the wooded areas, the differentiation is nearly impossible.

As mentioned earlier, the Celina problem involves a difficult separation with Conover on one hand and Miami on the other. Since Conover often is associated with the flatter areas, this separation is the less difficult of the two. Miami often competes with Celina

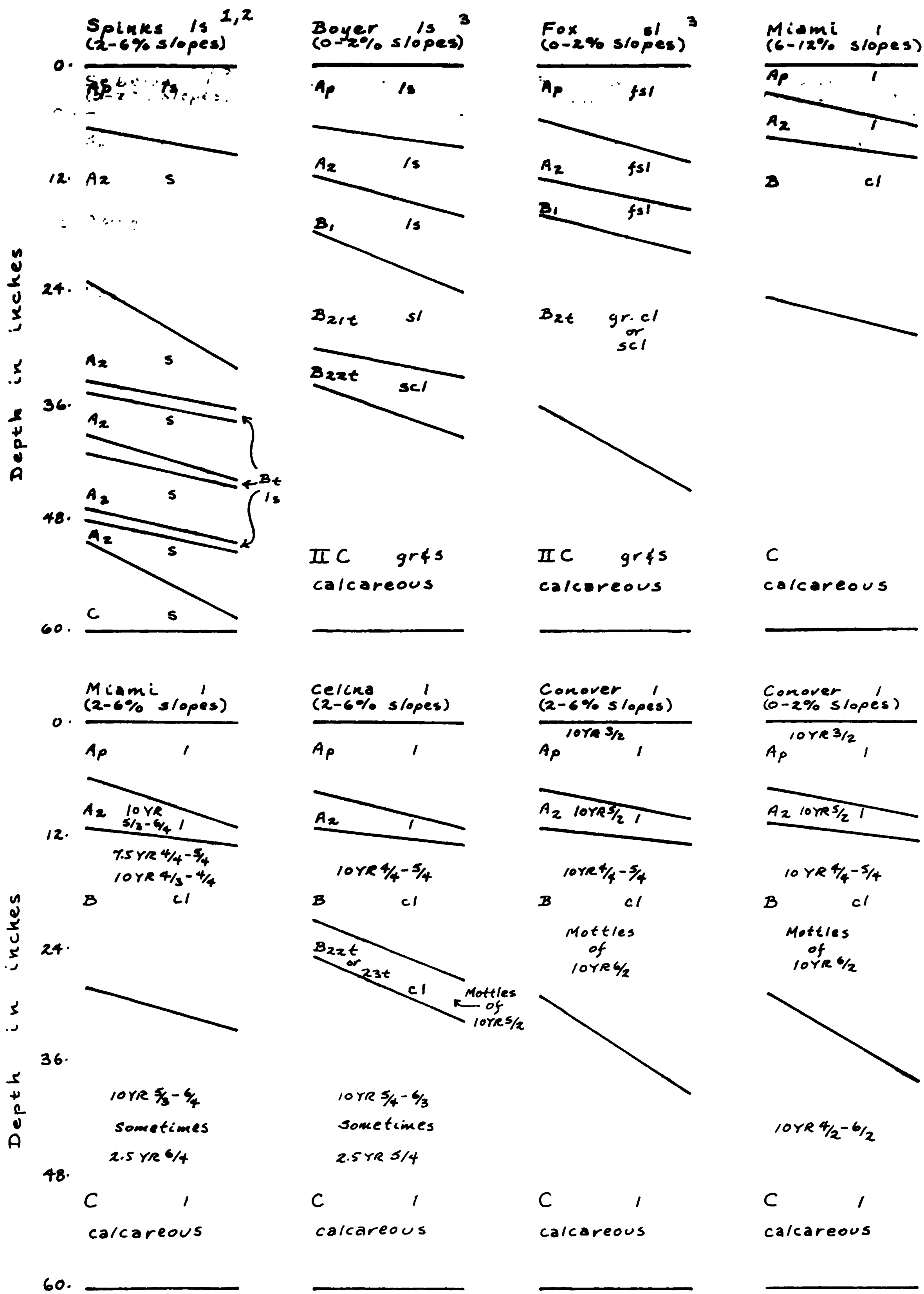
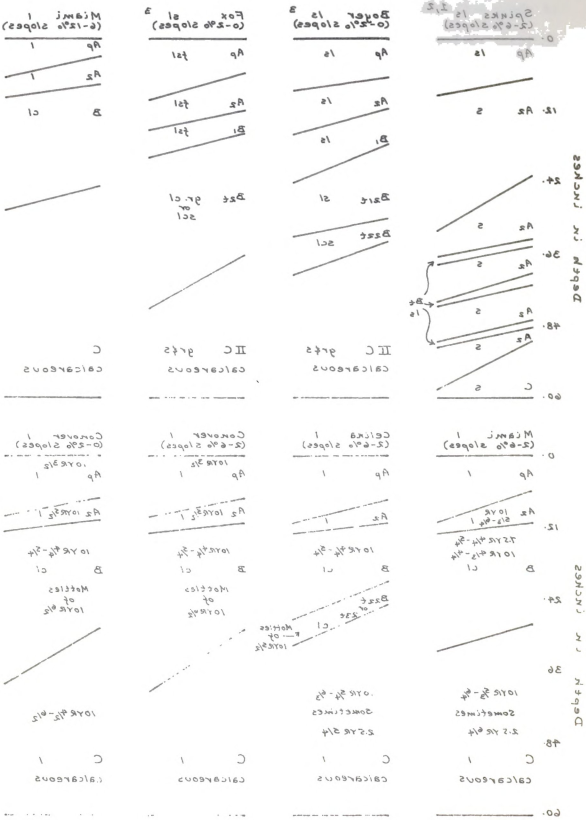


Fig. 3. Diagrammatic sketches of the 12 units studied.



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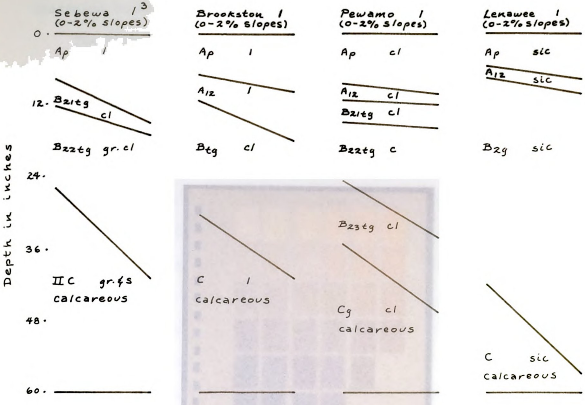

1 Abbreviations are explained in the Appendix.

2 In the Spinks profile, the horizon ranging from 23 to 59 inches is designated as A & B.

3 These soils are "two-storied," their profiles having formed in contrasting parent materials. The lithologic discontinuity is denoted by the Roman numeral horizon prefix.

4 The Celina unit was subsequently re-named "Miami loam, mottled subsoil phase".

Fig. 3 (Cont.)

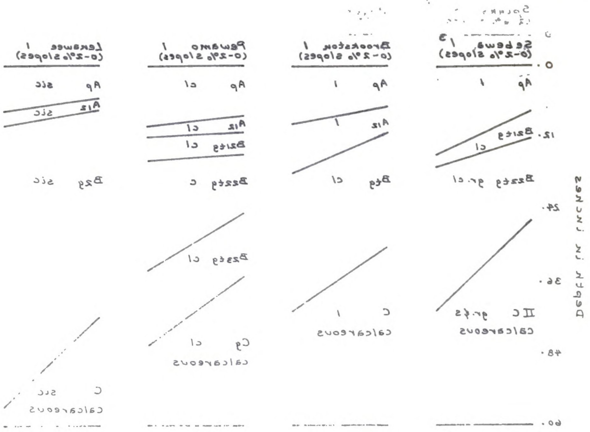

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Fig. 3 (Cont.)

Fig. 4. The 10YR hue page from a book of revised standard soil color charts.

for the same topographic position forcing the separation in these instances to be on a morphological basis.

The Miami B horizon in many pedons apparently undergoes seasonal wetting and drying to the extent that significant separation along major structural unit surfaces occurs. Into these crevices a certain amount of material from the A_2 horizon is deposited. If the color of the translocated A_2 material is 10YR 5/3, this material, when bored from the B horizon in the course of pedological examination, is often mistaken for drainage mottles of 10YR 5/2 (Fig. 5).

Likewise, when the matrix color of the calcareous C horizon is 10YR 5/3, as is often the case, and the B - C transition occurs at the 20 - 30 inch depth, another possibility of mistaken color identification exists.

One of the most perplexing phenomena occurs at the B - C contact in many Miami pedons. This contact acts as a temporary barrier to the passage of soil moisture resulting in a saturated zone in the lower B horizon (from the C contact to 6 - 8 inches above the C) even when the upper solum is at field capacity or lower (Fig. 5). This saturation is enough to produce chroma 2 colors although it seems the soil should not be as limited in use from a drainage standpoint as a conventional moderately-well drained soil.

The author of this dissertation fully supports the decision to change Celina to Miami, mottled subsoil phase in the Clinton County legend. He hopes that the interpretation of this unit is modified accordingly.

An attempt was made to devise a numerical scheme for measuring the relative homogeneity of the mapping units studied. In this

scheme a contrast value was attached to each observation as a measure of variation from the mapping unit. The 4 contrast values used were:

0 - No contrast - Phase, type, or series

1 - Low contrast - Soils of close resemblance

2 - Medium contrast - Soils of some resemblance

3 - High contrast - Soils of little resemblance

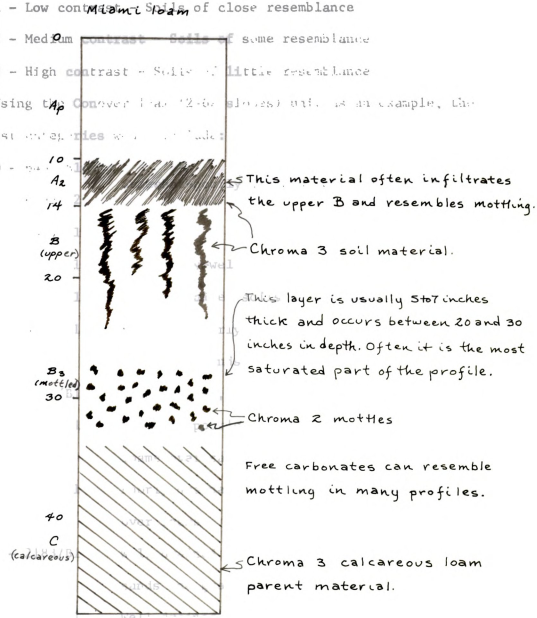
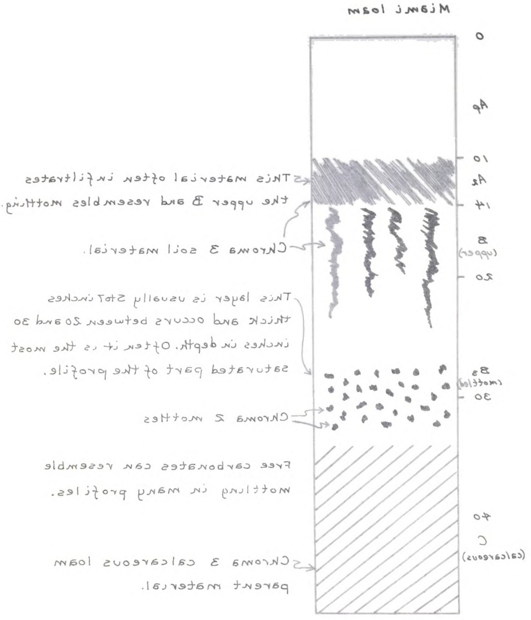


Fig. 5. Morphological characteristics of some Miami profiles which may result in their being confused with Celina.



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3 - High contrast - Soils of little resemblance

Using the Conover loam (2-6% slopes) unit as an example, the contrast categories would include:

0 -	6455/B1 6455/B2 6455/A1	Somewhat-poorly drained soils of the same series.
1 -	5355/B1	Moderately-well drained soils of the same catena.
	8805/A1	Poorly drained soils of the same catena.
	6303/A1	Somewhat-poorly drained soils formed in stratified, very fine sands and silts.
2 -	4505/B1	Well drained, loamy soils.
	6893/A1	Somewhat-poorly drained soils formed in sandy loams over sands and gravels.
	8613/A1	Poorly drained soils formed in fine sandy loams over loams.
3 -	2183/B1	Well drained soils formed in sandy loams over sands and gravels.
	3493/C1	Well drained soils formed in fine sandy loams.

The criteria for placing soils in these categories were drainage and texture. The same soil conceivably could occupy each category in succession when evaluated as an inclusion in the progressive analysis of the 12 mapping units. Obviously, it was necessary to regroup all

inclusions into contrast categories for each unit studied. Although this method involved a considerable amount of judgment and was subjective in many cases, the procedure was consistent for each unit.

For the Conover loam (2-6% slopes) unit, the partitioning of observations into contrast categories produced the following:

0 - No contrast - 32.2%

1 - Low contrast - 38.2%

2 - Medium contrast - 25.1%

3 - High contrast - 3.6%

From these results, this unit seems to be fairly well conceived and mapped, with about 70% of all observations either of no contrast or low contrast to the designated mapping unit name. This leaves only about 30% of the observations of medium contrast or greater, which might cause moderate to serious problems in interpretation for potential use. This is probably an optimistic evaluation because the 0 - no contrast category permits a variation in phase throughout the slope ranges. In a well drained unit, the same series might be found on 2% slopes and 25% slopes and included in the no contrast category. Use potential at the slope extremes would be critically different for such things as open-tilled crops, residential development, and playgrounds.

In order to obtain one numerical value by which each mapping unit could be rated and all compared, the percentage value of each group of observations was multiplied by the contrast value of the same group. For example, continuing with the Conover loam (2-6% slopes) unit:

Taxonomic unit	Number of observations	% of total observations	Contrast value	Weighted contrast value
4503/B1	6	7.1	2	14.2

The summation of weighted contrast values for all groups of observations (phases of soil series) within a mapping unit gives a weighted contrast value for the mapping unit. If every observation within the Conover loam (2-6% slopes) mapping unit agreed perfectly with the mapping unit designation, the analysis would be:

Taxonomic unit	Number of observations	% of total observations	Contrast value	Weighted contrast value
6455/B1	84	100.0	0	0

Since the weighted contrast value is the product of the percentage of total observations times the contrast value, the weighted contrast value is 0 and the unit is a perfect unit.

Conversely, if every observation within the Conover loam (2-6% slopes) mapping unit were of maximum contrast value, the analysis would be:

Taxonomic unit	Number of observations	% of total observations	Contrast value	Weighted contrast value
2183/B1	84	100.0	3	300

This does not mean that there are no similarities between the soil mapped and the soil found, or that they are mutually exclusive for all potential uses. It does mean that the soil was completely mismapped and that the difference between the call and the find was of most serious magnitude.

The weighted contrast value for Conover loam (2-6% slopes) is 102.8, which indicates this is one of the better units. In Table 6 the Clinton County mapping units studied are summarized as to agreement at different taxonomic levels and contrast values.

Table 6. Mapping unit evaluation and contrast summary.

Mapping units	Mapping unit number	Field sheets	Mappers	Total observations	Total taxonomic units
Spinks ls 2-6% slopes	2342/B1	2	2	57	16
Boyer ls[1] 0-2% slopes	2552/A1	4	2	54	17
Fox sl[1] 0-2% slopes	3443/A1	1	1	49	15
Miami 1 2-6% slopes	4505/B1	4	4	50	18
Miami 1 6-12% slopes moderately eroded	4505/C2	4	4	50	27
Celina 1 2-6% slopes	5355/B1	7	5	74	27
Conover 1 0-2% slopes	6455/A1	8	5	79	29
Conover 1 2-6% slopes	6455/B1	9	6	84	26
Sebewa 1[1] 0-2% slopes	8745/A1	3	3	62	16
Brookston 1 0-2% slopes	8805/A1	6	4	70	19
Pewamo 1 0-2% slopes	8815/A1	5	2	53	10
Lenawee sicl 0-2% slopes	8848/A1	1	1	50	4
Average		4.5	3.25	61.0	18.7

[1]Two-storied soils.

Table 6. (Cont.)

Mapping units	% phase agreement	% type agreement	% series agreement	% management group agreement
Spinks ls	5.3	5.3	5.3	17.5
Boyer ls	9.3	16.7	18.5	51.9
Fox sl	0	0	0	14.3
Miami l 2-6% slopes	24.0	28.0	44.0	50.0
Miami l 2-6% slopes moderately eroded	2.0	12.0	48.0	54.0
Celina l	6.8	9.5	12.2	32.4
Conover l 0-2% slopes	21.5	34.2	34.2	34.2
Conover l 2-6% slopes	26.2	32.2	32.2	33.3
Sebewa l	40.3	40.3	40.3	41.9
Brookston l	52.9	55.7	55.7	55.7
Pewamo l	37.7	58.5	58.5	58.5
Lenawee sicl	78.0	78.0	78.0	78.0
Average	25.9	30.9	36.6	43.5

Table 6. (Cont.)

Mapping units	% no-contrast observations	% low-contrast observations	% medium-contrast observations	% high-contrast observations	Weighted contrast value
Spinks ls	5.3	16.0	77.4	1.8	176.2
Boyer ls	18.5	37.2	40.9	3.8	130.4[1]
Fox sl	0	57.1	20.2	22.4	164.7[1]
Miami l 2-6% slopes	44.0	26.0	18.0	12.0	98.0
Miami l 6-12% slopes moderately eroded	20.0	30.0	10.0	40.0	168.0
Celina l	12.2	48.7	30.1	9.7	138.0
Conover l 0-2% slopes	34.2	35.4	22.8	7.8	104.4
Conover 2-6% slopes	32.2	38.2	25.1	3.6	102.8
Sebewa l	40.3	4.8	30.6	24.2	138.6[1]
Brookston l	55.7	22.8	15.7	5.6	71.0
Pewamo l	58.5	24.5	9.5	7.6	66.3
Lenawee sicl	78.0	12.0	4.0	6.0	38.0
Average	36.6	29.4	25.4	12.0	116.4

If the mapping units studied are plotted with their weighted contrast value on the ordinate and soil drainage on the abscissa, then a fairly good trend line may be drawn (Fig. 6). This trend line indicates increasing homogeneity as soils become more poorly drained. Most well drained mapping units have weighted contrast values from 120 to 160, while most poorly drained units range from 40 to 80. Soils of intermediate drainage classes follow the line quite closely.

Certain relationships may be drawn from this graph. Two-storied soils seem less homogeneous than one-storied soils. Apparently the restriction in concept imposed upon two-storied soils make them more difficult to find in sizeable bodies than one-storied soils. An exception would be Spinks, which is considered a one-storied soil, but which has a diagnostic, banded A_2 and B_t horizon rarely found consistently over large landscape areas in the Tri-County Survey Area. The author can recall an incident which happened soon after his arrival in Michigan and introduction to work in the Tri-County Survey Area. He was shown a "Spinks" profile in a pit which had been excavated for the basement of a small house. Around the walls of this pit could be seen the expression of the normal range of the Spinks concept with an adjacent Oakville profile representing the coarse boundary and a Boyer or Oshtemo the fine boundary.

Apparently the refinement of concept to the point where a set of morphological characteristics such as those represented by Spinks are separated at the series level is taxonomic progress. To attempt to map such taxonomic units with precision in an area such as the Tri-County Survey Area, however, is an exercise in futility.

Heterogeneity within a mapping unit seems to be the product of at least three factors:

1. Natural variation of soil individuals within a defined landscape position.
2. Error in taxonomic concepts.
3. Error in mapping the physical delineations.

It is conceivable ...

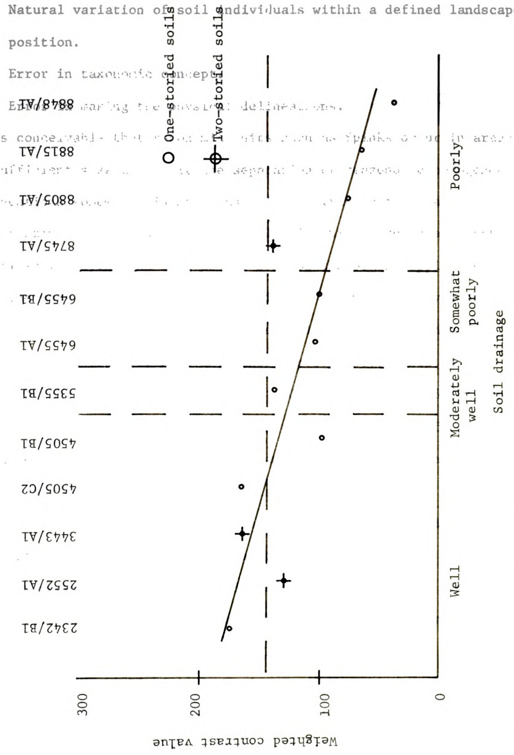
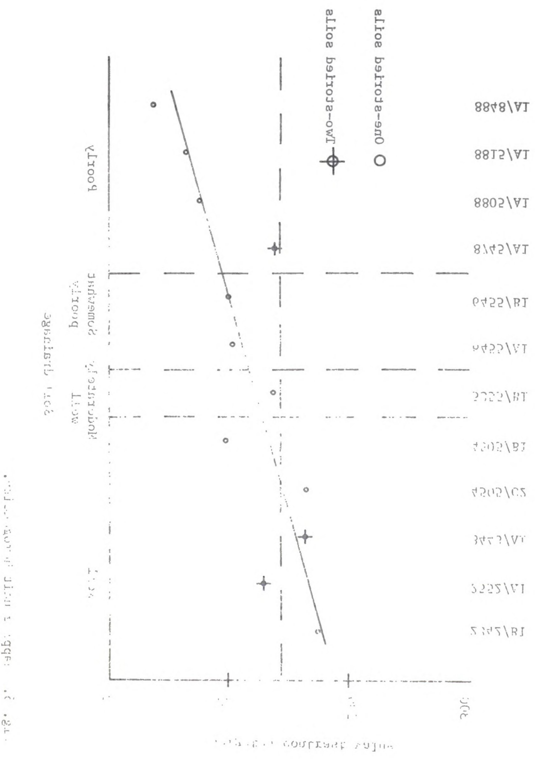


Fig. 6. Mapping unit homogeneity.



Soil drainage
Well
Moderately well
Somewhat poorly
Poorly
One-storied soils
Two-storied soils
2342/B1
2552/A1
3445/A1
4505/C2
4505/B1
5555/B1
6455/A1
6455/B1
8745/A1
8805/A1
8815/A1
8848/A1
300

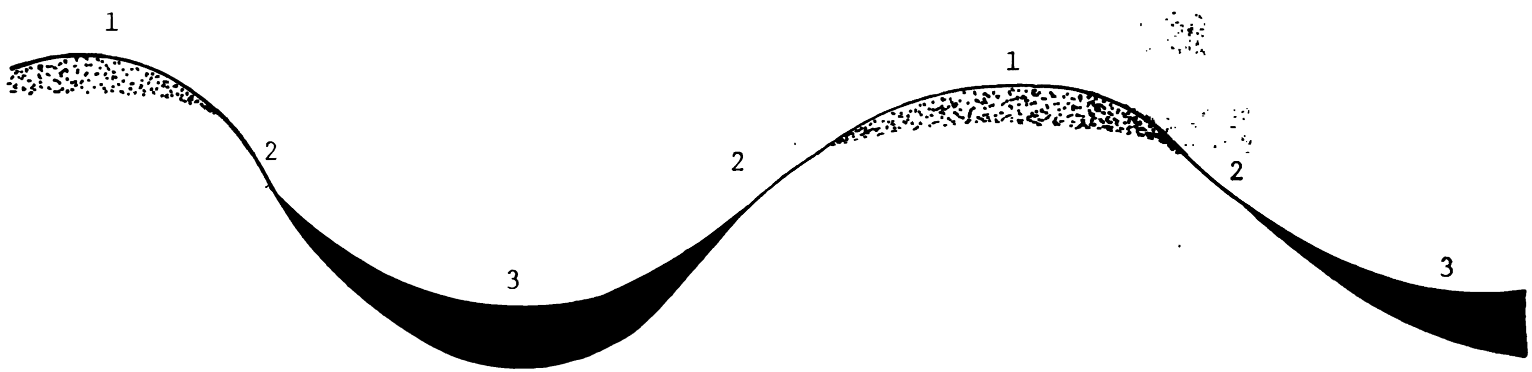
Heterogeneity within a mapping unit seems to be the product of at least three factors:

1. Natural variation of soil individuals within a defined landscape position.
2. Error in taxonomic concept.
3. Error in making the physical delineations.

It is conceivable that taxonomic units such as Spinks occur in areas of sufficient size to permit the separation of reasonable homogeneous delineations somewhere in Michigan. In the Tri-County Area it was like hunting a wil-o-the-wisp. Clearly, in this survey area, factor 1 prevailed for Spinks as well as for some of the other mapping units.

The most extensive toposequence in the Tri-County Survey Area is the Miami catena, formed on calcareous loam till and exhibiting perhaps more uniformity than any other toposequence. This is confirmed by the fact that mapping units 4505/B1, 6455/A1, 6455/B1, and 8805/A1 fall on or below the trend line in Fig. 6. Lack of homogeneity in unit 4505/C2 (Miami loam, 6-12% slopes, moderately eroded) may originate in a mapping bias which results in a soil surveyor weighing more heavily the side slopes than the ridges and depressions in the choppy, irregular terrain on which this unit normally occurs (Fig. 7). Unit 5355/B1 (Celina loam, 2-6% slopes) has no well-defined landscape position, as was mentioned previously. It also serves as a catch-all for soil individuals falling between Miami and Conover. Often it is a mixture of the two.

A plot of the Miami catena observation in the Miami catena mapping units studied reveals the weakness of the Celina concept (Fig. 8). In every unit studied except the Brookston loam (0-2%

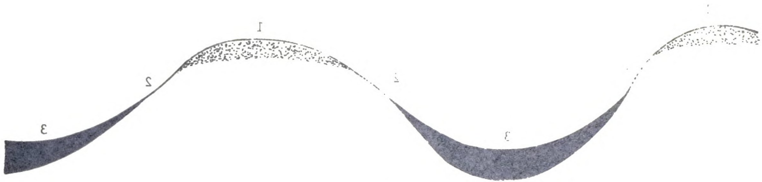


Landscape position 2 is where the soil surveyor normally samples and finds 4505/C2.

Landscape position 1 is usually 4505/B1, or is capped with sandy material giving rise to other (possibly two-storied) units.

Landscape position 3 is more poorly drained and more extensive than most surveyors realize.

Fig. 7. Soil landscape on which Miami loam (6-12% slopes, moderately eroded) was mapped (plan view).



Landscape position 1 is where the soil surveyor normally samples and finds 4505/C2.

Landscape position 2 is usually 4505 B1, or is capped with sandy material giving rise to other (possibly lower yield) units

Landscape position 3 is more [illegible] and more extensive than most surveyors realize.

Fig. 7. Soil landscape on [illegible] loam (5-12% slopes, moderately eroded) was mapped (plan view)

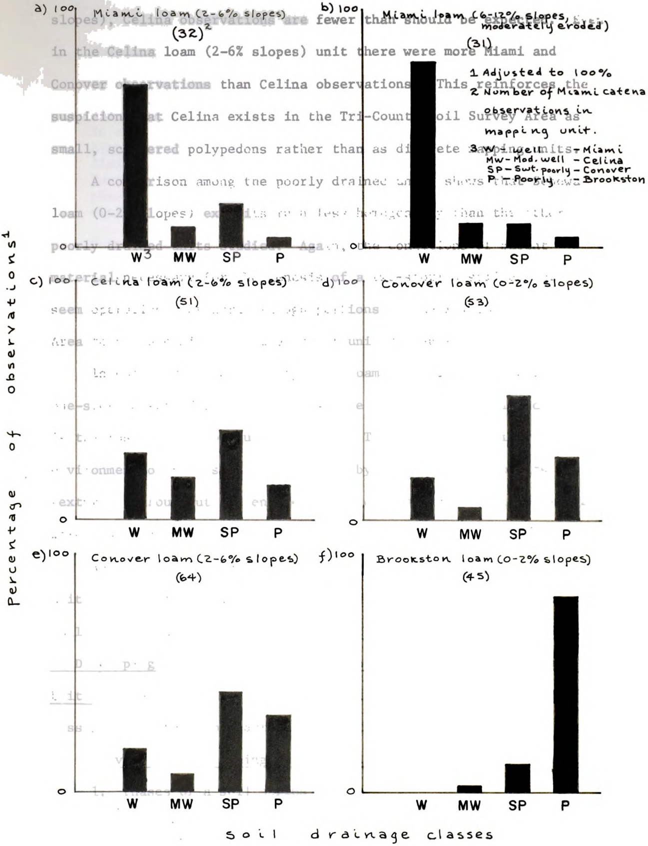


Fig. 8. Distribution of Miami catena observations in Miami catena mapping units.

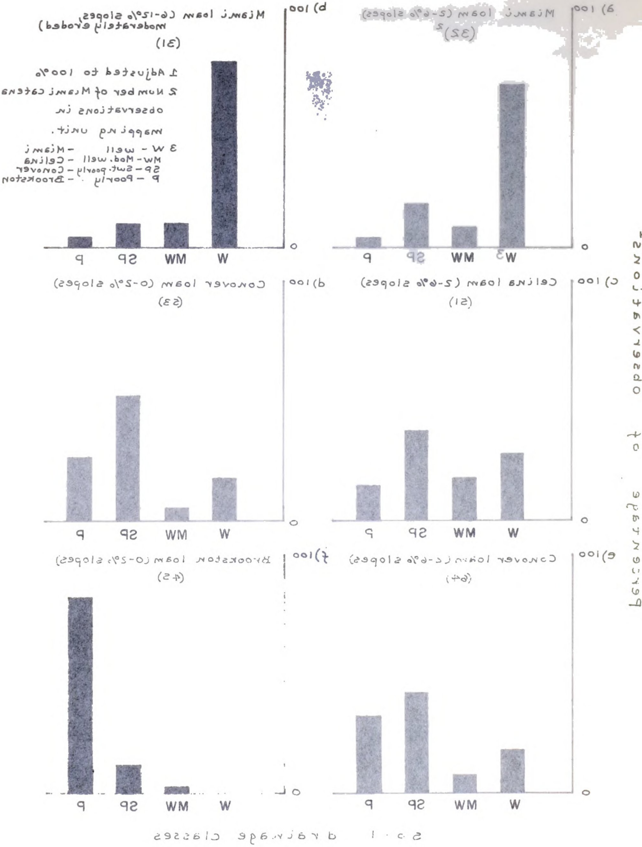


Fig. 8. Distribution of Miami catena observations in Miami catena mapping units.

slopes), Celina observations are fewer than should be expected. Even in the Celina loam (2-6% slopes) unit there were more Miami and Conover observations than Celina observations. This reinforces the suspicion that Celina exists in the Tri-County Soil Survey Area as small, scattered polypedons rather than as discrete mapping units.

A comparison among the poorly drained units shows that Sebewa loam (0-2% slopes) exhibits much less homogeneity than the other poorly drained units studied. Again, the conditions of parent material necessary for the genesis of a two-storied soil do not seem operative over large enough portions of the Tri-County Survey Area to produce significant areas of uniform Sebewa.

In contrast, Lenawee silty clay loam (0-2% slopes), which is a one-storied soil formed from lacustrine clay and silty clay deposits, is the most homogeneous unit studied. The relatively uniform genetic environment of this soil is evidenced by the uniformity of its surface texture. Throughout the entire set of observations studied only 12% were loam and only 10% were sandy.

About the time the field study of these Tri-County mapping units was completed, the U.S.D.A.,Soil Conservation Service released Soils Memorandum - 66, Application of the Soil Classification System in Developing or Revising Series Concepts and in Naming Mapping Units, dated October 9, 1967. From this memorandum the following passage is quoted (Soil Survey Staff, 1967):

Conventions for Naming Mapping Units

1. Phases of a soil series
Most series consist of a set of soils with ranges in soil slope, depth, stoniness, or other features significant to their use. Subdivisions according to differences in such features are recognized as phases. Some series lack such subdivisions and can

be called monophase series, at least so far as is known now.

Phases are set apart in a soil survey area because of differences in behavior beyond those differences that can be related directly to soil series. Each phase should differ from every other phase in the same series in usefulness or response or both. Thus, for example, phase separations should carry with them differences in one or more of use suitability, management requirements for crop production, crop yields, forage production, site index, limitations for septic tanks, and suitability for road grades. Furthermore, the differences in behavior between any pair of phases of a single series should be larger than errors of estimate.

Mapping units set apart in field work are to be named as phases of soil series, including soil types considered as one kind of phase, provided they meet the requirements spelled out below under Alternative I or Alternative II.

<u>Alternative I.</u> Three-fourths or more of the polypedons fit within
the phase of the series that provides the name for
the mapping unit
or fit in
closely similar phases of the same series
or of
other series in closely similar families of the
same subgroup,
in
parallel families of like subgroups,
or in
other families closely similar in behavior.
The most extensive kind of soil must fall within the range of the phase providing the name for the mapping unit. As a rule, that kind constitutes more than half. The most extensive soil, however, may constitute no more than 35 percent of the mapping unit if 15 percent or more consists of a taxadjunct to the series. Each of the inclusions of soils of closely similar series may constitute as much as 25 percent of the mapping unit but their aggregate proportion must not exceed 50 percent. Minor proportions of strongly contrasting soils are also allowed as inclusions but none of them individually may constitute more than 10 percent and their aggregate proportion may not exceed 15 percent.

....

<u>Alternative II.</u> Three-fourths or more of the polypedons fit within a
taxadjunct to the series that provides the name
for the mapping unit
or fit in
some other series in closely similar families
of the same subgroup,
in

parallel families of like subgroups,
or in
other families closely similar in behavior,
but the series providing the name does not occur in the survey area.
The proportions of the most extensive kind of soil and of similar and contrasting inclusions are the same as under Alternative I.[1]

Alternative I covers the common situation that will be met in correlating soils of individual survey areas. Follow that alternative as usual practice.

Follow Alternative II only if the most extensive kind of soil in a mapping unit is a taxadjunct and the series providing the name is not represented in a survey area.

Since several terms in the preceding passage have been redefined in the memorandum, the definitions are given here:

closely similar families - "families alike on one or more counts such as texture, carbonates, temperature or mineralogy."

closely similar phases - "phases which may belong to the same series, to other series in parallel families of like subgroups, to other series in closely similar families, or to taxadjuncts."

parallel families - "families in different subgroups but nearly equivalent in texture, mineralogy, and other family differentiae."

phase - subdivisions of soil series according to differences in such features as soil texture, slope, depth, stoniness, or other features significant to their use.

polypedons - the contiguous, taxonomically similar, basic soil units (pedons) which, together, form the soil individual.

strongly contrasting soils - this term is not defined in Soils

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[1]Both Alternative I and Alternative II were printed in the original document as one paragraph each. The options were separated typographically by the author of this dissertation in a desperate attempt for clarity.

Memorandum - 66 (one might assume the normal English language meaning).

taxadjunct - a group of soils barely outside the limits of previously defined series. The magnitude of variation from the normal series range is only slightly larger than normal error of observation.

That difficulty and confusion should accompany the naming of mapping units should come as no surprise after reviewing the guidelines. However, an example of the improvement which can result from a process as simple as correct mapping unit identification is given in Table 7. In this instance not one line has been changed on the soil maps: all that is changed are the names of some of the mapping units to more accurately reflect their composition. The relatively small investment in time and effort required to analyze these units by the point-intercept transect method seems insignificant when the yield is as great as a 100% improvement in phase agreement. It would seem that mapping unit analysis should be a standard procedure required by the National Cooperative Soil Survey in all of its endeavors. Likewise, it would be desirable to have a section in each soil survey report devoted to mapping unit analysis with the percentage composition of each major mapping unit given in detail.

As a result of this study, in early 1968 a recommendation of name changes essentially the same as those listed in Table 7 was made to the Tri-County soil survey party.

In view of the previous definitions of mapping units from Soils Memorandum - 66 and the study of mapping unit composition in the Tri-County Survey Area, the inadequacy of the mapping unit definition in the Soil Survey Manual becomes obvious (Soil Survey Staff, 1951, p. 277). Mapping units are more heterogeneous than previously

Table 7. Proposed changes in the names of the 12 Clinton County mapping units studied.

Mapping unit number	Existing name	Percent agreement by phase	Percent agreement by series
2342/B1	Spinks loamy sand (2-6% slopes)	5	5
2552/A1	Boyer loamy sand (0-2% slopes)	9	19
3443/A1	Fox sandy loam (0-2% slopes)	0	0
4505/B1	Miami loam (2-6% slopes)	24	44
4505/C2	Miami loam (6-12% slopes, moderately eroded)	2	48
5355/B1	Celina loam (2-6% slopes)	7	12
6455/A1	Conover loam (0-2% slopes)	22	34
6455/B1	Conover loam (2-6% slopes)	26	32
8745/A1	Sebewa loam (0-2% slopes)	40	40
8805/A1	Brookston loam (0-2% slopes)	53	56
8815/A1	Pewamo loam (0-2% slopes	38	59
8848/A1	Lenawee silty clay loam (0-2% slopes)	78	78
Average		25	36

Table 7. (Cont.)

Mapping unit number	Proposed name	Percent agreement by phase	by series
2342/B1	Oakville loamy sand (2-6% slopes)	57	68
2552/A1	Oshtemo-Oakville loamy sands (1-6% slopes)	54	65
3443/A1	Oshtemo-Oakville loamy sands (1-6% slopes)	42	72
4505/B1	Miami-Owosso sandy loams & loams (2-6% slopes)	54	58
4505/C2	Miami sandy loams (3-12% slopes)	28	48
5355/B1	Conover-Miami loams (1-6% slopes)	41	47
6455/A1	Conover-Brookston loams (0-6% slopes)	51	52
6455/B1	Conover-Brookston loams (0-6% slopes)	54	56
8745/A1	Sebewa loams (0-2% slopes)	40	40
8805/A1	Brookston loams (0-2% slopes)	53	56
8815/A1	Pewamo loams (0-2% slopes)	38	59
8848/A1	Toledo clay loam (0-2% slopes)	78	78
Average		50	58

thought, much more so. And, if the trend toward refinement of taxonomic definitions continues without improvement in the precision of making soil delineations, mapping units should continue to become even more heterogeneous. To ensure continuing quality of soil surveys and maintenance of predictive value for mapping units, four steps seem mandatory:

1. Maintenance of a well-trained soil survey staff of high scientific competence and good morale.
2. Systematic transect studies to define composition of mapping units and facilitate increased precision of delineations.
3. The inclusion in each soil survey report of a section on mapping unit analysis giving percentage composition of each of the major mapping units.
4. Availability of competent personnel to interpret mapping units and conduct more detailed surveys (on-site investigations) as needed after the progressive survey has been completed.

B. STANDARD QUARTER-SECTION MAPPING ANALYSIS

If one accepts the mapping unit analysis in the previous part of this section as a measure of mapping unit homogeneity, then he must wonder whether heterogeneity is a characteristic of a mapping unit or a result of the individual mapper's lack of efficiency in the delineation of the unit. Since this is a valid question - indeed one which has arisen whenever soil surveyors discuss mapping quality in a particular area - this portion of the research was designed to measure the variability of mapping among men actually engaged in the Tri-County soil survey.

Five operators who were participating in the modern Tri-County survey are considered in this portion of the study. The operators and their length of professional experience are listed in Table 8:

Table 8. Mapping experience of operators in mapping analysis study.

Operator	Years experience in soil survey
1	17
2	17
3	5
4	4
5	2

In its discussion of plotting soil boundaries in the field, the Soil Survey Manual considers the individual's soil mapping ability in the following manner:

> Soil mapping is a technical art. Men lacking sound training in soil science should not be expected to do well, especially those unfamiliar with the principals of the earth sciences.

> Yet some well-trained men, even men well above the average in competence in soil classification, lack the ability to plot soil boundaries accurately. Some can learn slowly, whereas others are unable to develop good skills. A competent soil mapper is able to abstract the essentials of the pattern of soil landscapes before him and sketch this pattern on the map; then, in reverse, from the lines and symbols on the map, he visualizes the soil pattern they collectively represent. His lines and symbols are drawn carefully. They are clear and neat (Soil Survey Staff, 1951, p. 321).

One might reasonably expect a certain degree of variation in taxonomic and mapping unit concept, and method of field mapping among a group of soil surveyors in spite of the party leader's best efforts for uniformity. For this reason the present study was undertaken.

The author had a revealing experience in his attempt to obtain the assistance of professional soil surveyors to conduct this portion of the study. Apparently there was a reluctance in some competent, experienced soil surveyors to map, with their peers, a quarter section in a controlled experiment. Whether this was a result of shyness, conservatism, or a natural fear of "putting one's skill on the line" is a matter of conjecture. The author was left with the distinct impression, however, that many soil surveyors are more willing to speculate on the proficiency of their fellow surveyors than to put their own proficiency to the test.

Included in the list of operators is the author of this dissertation. He was acutely aware of the risk of personal bias in doing this and sought to eliminate it whenever possible. The fact that he scored so poorly in the subsequent analysis is a measure of his success in the dual role of operator and evaluator.

Two operators mapped the same section twice; the author and Operator 5. In each case, several months separated the first mapping attempt and the second. Operator 5 mapped the quarter section

at the beginning of the field season, and because he felt he had been "rusty" from inactivity, asked to map it again in the fall when his concepts were sharper. The other remapping was done by the author to study the effect of a larger scale and more survey time on the purity of the delineations.

In addition to the comparisons in the preceding paragraph, two other comparisons were possible. The area to be studied had been surveyed in 1933 in the original progressive survey of Ingham County and again in 1952 for research purposes. Of course, these surveys were at different scales and intensities and were accompanied by different legends. In the future we shall refer to these two additional operators in the following manner:

Operator	Identification
6	Research Mapper (1952)
7	Progressive Surveyor (1933)

In the evaluation of these operators, allowance was made for variations in mapping unit definition. The broadest definitions were found in the 1933 survey, as one might expect.

Except as noted previously, mapping was done on etched acetate overlying an aerial photograph of the area, at a scale of 1:12,000, or 1 inch = 1,000 feet. Each photograph was accompanied by an instruction sheet (Fig. 9). This was an attempt to establish a uniform mapping environment among the operators, one resembling actual survey conditions as much as possible.

An examination of the aerial photograph of the quarter-section used in this portion of the study reveals some of the characteristics of the soil landscape (Fig. 10). The drainage is subdued as one might at the beginning of the field season, was because he felt he had been "rusty" from inactivity [illegible] again in the fall these concepts

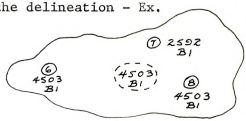
1) Map on acetate at normal Tri-County intensity - this means approximately 320 acres per day, or 160 acres in 1/2 day or less.

2) Record exact time mapping began.

3) Please record each boring and the soil found there - Ex. 1 4503 B1

4) Record and underline all borings attempted and abandoned before the soil could be determined - Ex. 17

5) If more than one soil is found in a delineation, please encircle your decision as to the nature of the delineation - Ex.



6) Please refill all auger holes because of cattle, and to leave as little indication as possible to the next man as to where you bored.

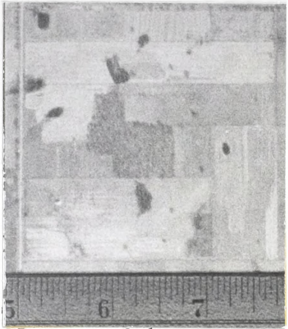
7) Record exact time mapping was completed.

8) Pertinent notes may be recorded on acetate.

9) I will ink the acetate.

10) Thanks.

Fig. 9. Operator instructions for quarter-section mapping analysis.



Scale
1 inch = 1000 feet

Fig. 10. Aerial photograph of the quarter-section analyzed in this study.

expect in an area as young as this. There are no well-defined drains in the area. There are some 9 depressions showing dark color in a belt running northwest to southeast across the quarter-section. In these areas the water table is at the surface, or standing water is on the surface. Darker soil areas, particularly along the southern and western boundaries, indicate imperfectly or poorly drained soils. Near the center of the quarter-section is a copse of woods about 10 acres in extent. A small building may be seen near the southwestern corner.

After studying Fig. 10, one is no longer perplexed at the variety of transect patterns indicated in Fig. 11. One tries, when mapping, to see and sample all the significant areas. And while this quarter-section may seem to contain a complex soil pattern, it resembles closely much of the land area in the southern one-third of the Lower Peninsula of Michigan.

The Soil Survey Manual gives fairly detailed instructions pertaining to the location of soil boundaries in the field:

> Soil boundaries are located on the mappers route or line of traverse and are sketched accurately on the base. Foot traverses need to be near enough together for accurate plotting between locations. In detailed basic soil surveys, the minimum distance between routes or traverse lines is about 1/8 to 1/4 mile, say about 800 to 1,600 feet, depending upon the scale of the map and the complexity of the soil pattern. Even with traverses at around 800 to 1,000 feet, some side traverses are needed to locate boundaries and to identify soils. Although soil boundaries are not actually traversed, they must be plotted from observations made throughout their course in detailed soil mapping.
>
> Once identified, the boundaries between most soil types, phases, and other mapping units coincide with observable features on the surface, such as the foot of a slope, the crest of a ridge, the margin of a swamp forest, a change in color of surface soil, and so on. Such correlation between surface features and soil boundaries require continual testing.

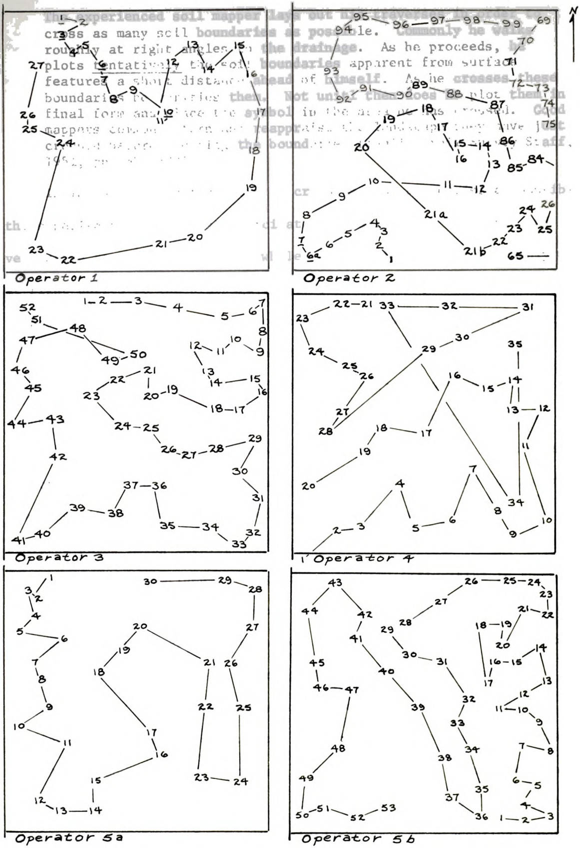


Fig. 11. Transect pattern among operators.

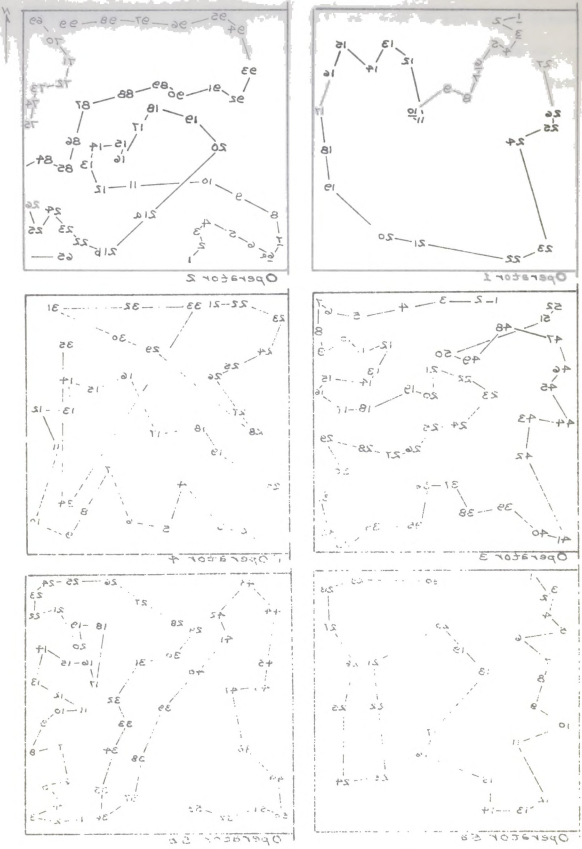


Fig. 11. [illegible] among operators.

> The experienced soil mapper lays out his traverses in order to cross as many soil boundaries as possible. Commonly he walks roughly at right angles to the drainage. As he proceeds, he plots tentatively the soil boundaries apparent from surface features a short distance ahead of himself. As he crosses these boundaries he verifies them. Not unitl then does he plot them in final form and place the symbol in the area he has crossed. Good mappers commonly turn and reappraise the landscape they have just crossed before plotting the boundaries finally (Soil Survey Staff, 1951, pp. 321-322).

In laying out his transects to cross as many boundaries as possible, the experienced mapper must anticipate boundaries from landscape and vegetative features. Likewise, while the admonition to walk roughly at right angles to the drainage is good, it lacks impact when drainage is poorly defined, sub-surface, or complex. Actually, the laying-out of traverses is nearly always a mental process, with nothing plotted on the map in advance, and therefore highly subject to bias. The author had long suspected that even the way an individual entered a mapping area and made his traverses was a function of bias. Since the author was able to plot the operators' traverses from their logging of sampling sites, they are included here as a basis for comparison of traverse paths among individuals (Fig. 11).

Lack of well-defined drainage may have been influential in the diversity of the transect patterns. There are certain resemblances, however. Emphasis seems to be concentrated on the east-west direction in the pattern of Operators 1 through 4. Operator 2 was mapping the quarter-section lying immediately to the east also, which may have influenced his transect direction. Operator 4 interrupted at observation 20 and continued the next day. In spite of these deviations, the east-west pattern seems dominant in the work of Operators 1 through 4 as opposed to Operator 5, who visualized the area as presenting a north-south problem, both in June and in October.

The maps resulting from the efforts of these operators may be observed in Fig. 12. It becomes immediately obvious that Operator 1 made the most generalized map and Operator 3 the most detailed. Between these extremes are Operators 5a, 4, and 2, ranked in order of increasing detail. When Operator 5 made his second map, he increased his number of observations by 23, but his delineations by only 5 (Table 9). Although Operator 3 made the second greatest number of borings, and the greatest number of delineations, his time was second fastest of the group. This operator customarily carried two augers with him, and followed the same procedure in this exercise. A safe guess would be that 1/3 of his observations were made with the screw auger, which reduces boring time considerably, and, in some cases, is just as satisfactory as the larger and slower bucket auger. Table 9 also shows the nearly twofold variation in transect distance, observations, and delineations among operators.

The standard by which these maps were evaluated is shown in Fig. 13. This is the grid pattern and resulting taxonomic identification of observations logged to characterize the standard quarter-section. Three areas - the southwest, the north central, and the southeast - were judged complex enough to investigate in greater detail than the 200 foot observation intervals on 400 foot transects which were applied to the entire area. In these highly complex areas, observations were made at every grid intersection along pre-determined vertical, horizontal, and diagonal transects. The grid would permit observations at 100 foot intervals horizontally and vertically and at about 141 foot intervals diagonally. This observational sequence was varied at only two places: D-21 where a small building prevented observation, and V-8 where the observation was made inadvertantly at V-7.

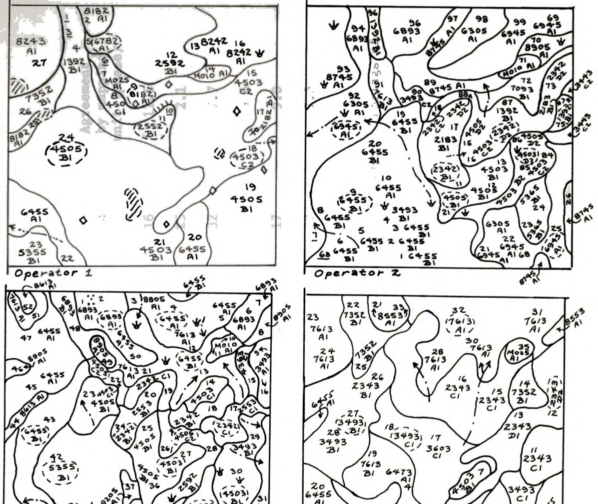
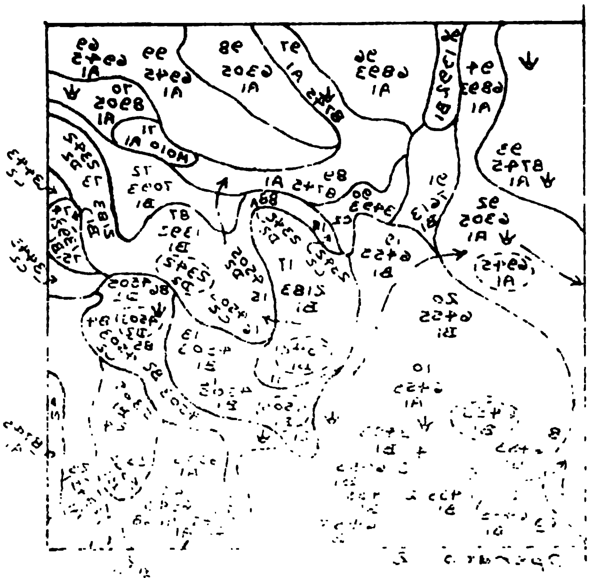
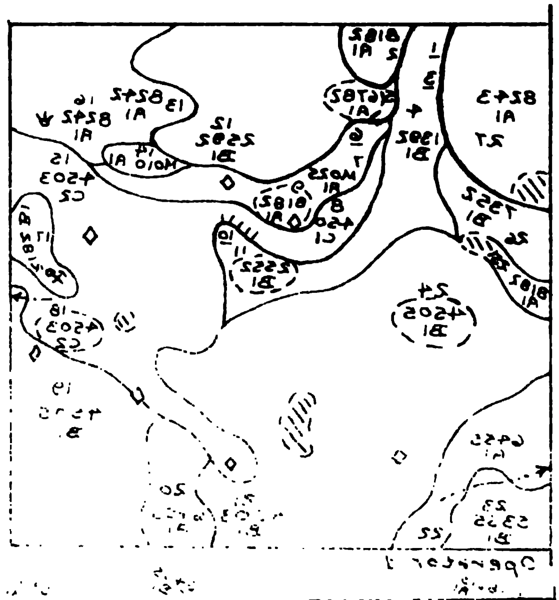


Fig. 12. Soil maps of standard quarter-section.





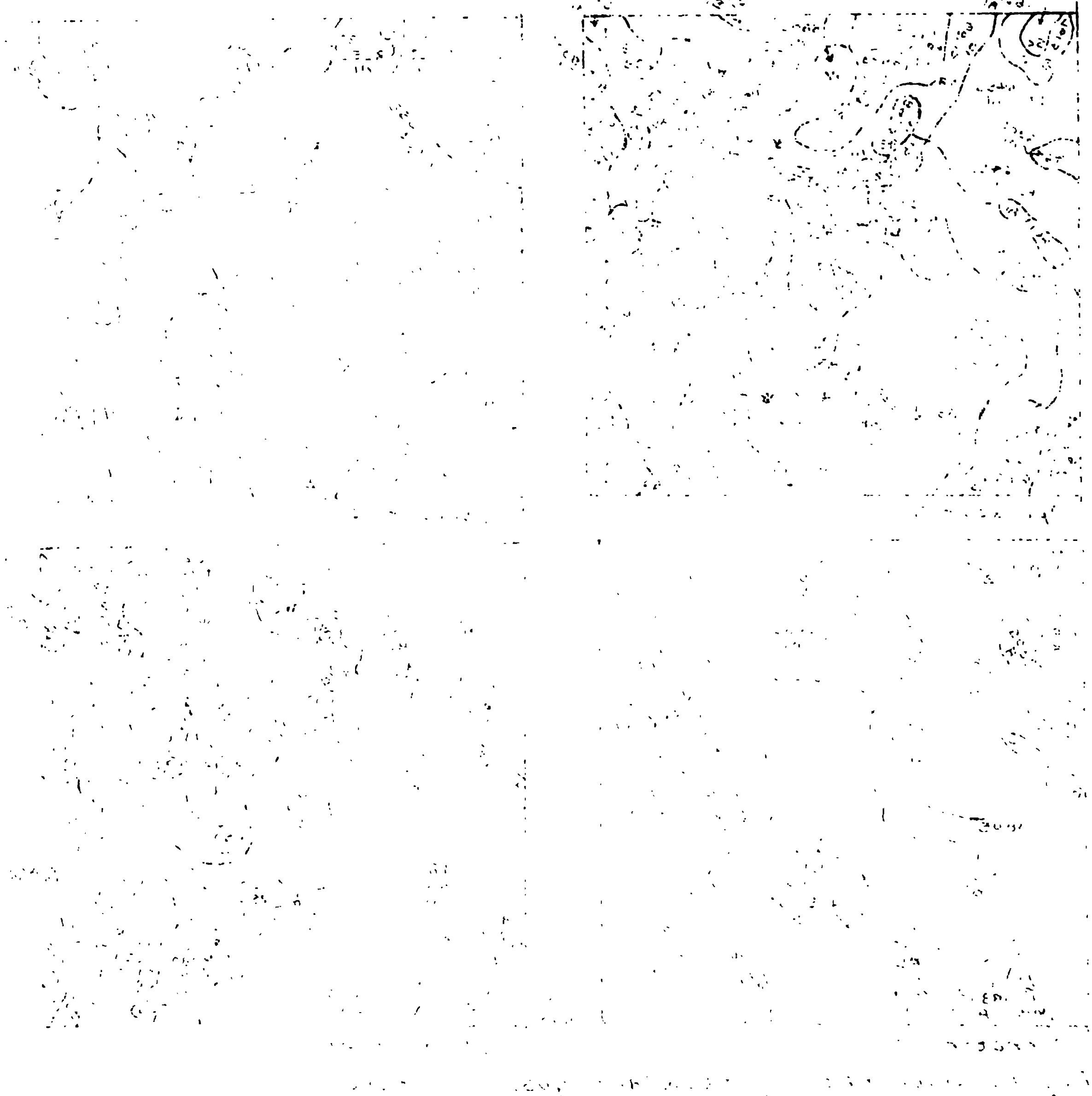


Table 9. Standard quarter-section mapping analysis.

Operator	Mapping time hr.	Mapping time min.	Observations	Boring[1] time hr.	Boring[1] time min.	Transect distance mi.	Delineations	Agreement by mapping unit (phase)
1	3	20	27	2	15	1.8	16	11.6
2	5	45	50	4	10	3.0	25	2.1
3	4	05	52	4	20[2]	3.5	32	7.7
4	4	30	35	2	55	3.7	21	3.6
5a[3]	4	45	30	2	30	2.5	17	9.0
5b[4]	6	10	53	4	25	3.4	22	7.5

---

[1]Based on an average time of 5 minutes to bore a hole to 66 inches with an orchard auger. Borings of lesser depth and screw auger borings are quicker.

[2]This exceeds Operator 3's total mapping time which is, of course, impossible.

[3]Operator 5 in June.

[4]Operator 5 in October.

A sample of the notes recorded at each observation site is given in Fig. 14. For each sampling site, depths, horizon identification, color, and texture were recorded. In addition, special features such as effervescence, [illegible] were [illegible]

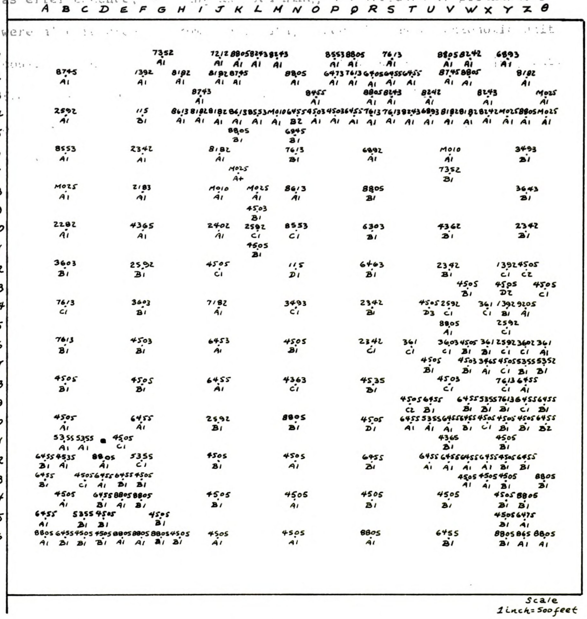


Fig. 13. A plot of taxonomic units at each gridded observation.

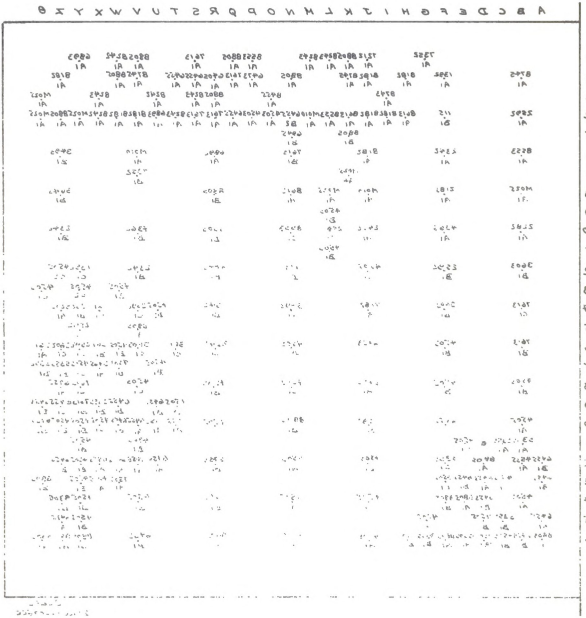


Fig. 13. A plot of ... at each graded observation

A sample of the notes recorded at each observation site is given in Fig. 14. For each sampling site, depths, horizon identification, color, and texture were recorded. In addition, special features such as effervescence, mottling and staining, and presence of groundwater were also recorded. From these data, a decision as to taxonomic unit could be made in a manner more systematic than by snap field judgment. From these data, likewise, one may obtain an appreciation of the range of characteristics encountered in trying to fit a set of morphological observations into a defined taxonomic unit. In the course of normal mapping observations, much morphological detail goes unobserved or is intentionally ignored, depending on whether the mapper is a cursory observor or a synthesizer. Perhaps this is in keeping with Koestler's statement that the greatness of the human mind lies in its ability to forget (Koestler, 1964, p. 190). Whether this be true or not, the pedons lying outside the range of taxa represented by the mapping unit symbol, which were once called "odd balls," are now given the more respectable designation of "inclusions."

These observations, evaluated and plotted as taxonomic units, are shown on the grid base in Fig. 13. Slope and aspect are likewise plotted in Fig. 15. These data, together, were considered to be the best means available to evaluate the accuracy of the mapping of the various operators. The maps were reproduced on acetate and superimposed on the grid which had been reduced to the mapping scale of 1 inch = 1,000 feet. Gridded observations were recorded and evaluated for each delineation. Observations falling on delineation lines were not counted. A summary of this evaluation is given in Table 9. Here survey time, observations, traverse distances, and number of delineations are listed, along with agreement of gridded observations with mapping

Observation	Z14	Z16	Z17	Z19	Z20	Z22	Z25
Unit	9205/A1	3602/C1	5355/B1	6455/C1	4505/B1	6455/B1	6475/A1
Slope	2%	7½%	5½%	6½%	4%	4%	1%
Erosion	1	1	1	1	1	1	1
Aspect	→	↘	↘	↗	→	→	↓
	Ap 10YR 3/2-4/2	Ap 10YR 4/2	Ap 10YR 3/2	Ap 10YR 3/2	Ap 10YR 3/2	Ap 10YR 3/2	Ap 10YR 3/2
6	sl-l	ls A2					
12	A1 10YR 3/2	10YR 5/4	ls-sl A2	l B21 10YR 4/3	l B1 10YR 4/4	l B1g 10YR 4/2	l B21 10YR 5/1-4/2
18	sl A1 buried 10YR 3/2 ls	ls B1 10YR 5/4	10YR 5/3 l B2 10YR 4/2-4/3	l B22 10YR 4/4 c C1	l B2 10YR 4/4	c B2g 10YR 4/3	scl B22 Mottled 10YR 5/6-5/2 scl ↓ sl ↓ s (coarser with depth)
24	Note: ~6" of the upper A1	sl B2 10YR 4/4		Mottled 10YR 4/4-5/2		c e stopped	C1 10YR 5/1
30	could have been separated because it dried	scl	c II B3 10YR 5/4	cl e C2	l II C1	by rock at 27"	occasional gravel ½-1" l-sl
36	more rapidly A2 buried 10YR 5/3	B3 10YR 4/3		Mottled 10YR 6/4-7/1	Mottled 10YR 5/6-6/2 Mn staining	Head of basin-like depression	e C2 10YR 5/4
42	ls-s B buried 10YR 4/4 ls-sl	sl II C 10YR 4/3 s	sl III C 10YR 6/1 l	l ev + Groundwater at 30"	sl II C2 Mottled 10YR 5/4, 6/2, 3/4 sl		ls-s es
48	+	+	+		+		+
54	This profile is located in a drain. Groundwater at 55"		Groundwater at 36" in 15 min		Groundwater at 30"		Groundwater at 36" in 15 min.

Fig. 14. Log of a portion of notes of observations on quarter-section grid.

OBSERVATION	Z14	Z16	Z17	Z19	Z20	Z22	Z25
Unit	3205/A1	3602/C1	5335/B1	6455/C1	4505/B1	6455/B1	6475/A1
Slope	2%	7½%	5½%	6½%	4%	4%	1%
Erosion	1	1	1	1	1	1	1
Aspect	→	↘	↘	↗	→	→	↓
	Ap	Ap	Ap	Ap	Ap	Ap	Ap
	10YR3/2-4/2	10YR4/2	10YR3/2	10YR3/2	10YR3/2	10YR3/2	10YR3/2
6	Sl-1	ls					
12	A1 10YR3/2	A2 10YR3/4	[illegible] A2	Bs1 10YR4/2	[illegible] 10YR4/4	B19 10YR4/4	Bs1 10YR3/4-4/2
18	Sl A1 buried 10YR3/2	ls B1 10YR3/4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]
30	[illegible]		[illegible]			[illegible]	[illegible]
36	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
42	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]
48	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]
54	[illegible]		[illegible]				[illegible]

delineations.

The incredibly low agreement is startling. Most of the operators had assumed they were performing near the standard of accuracy of

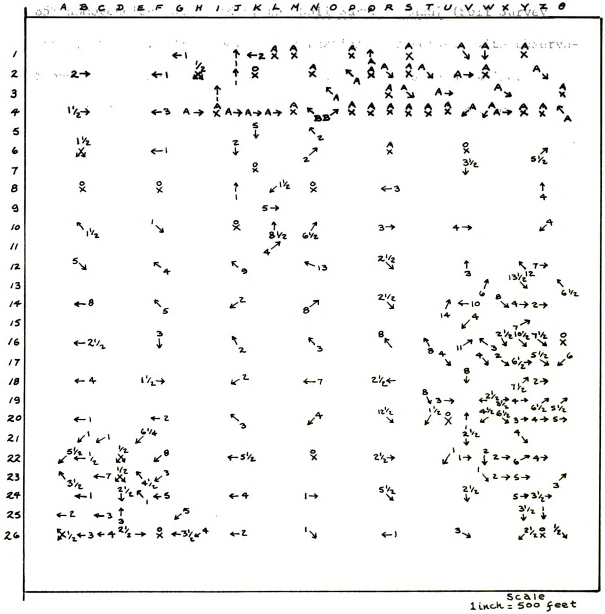
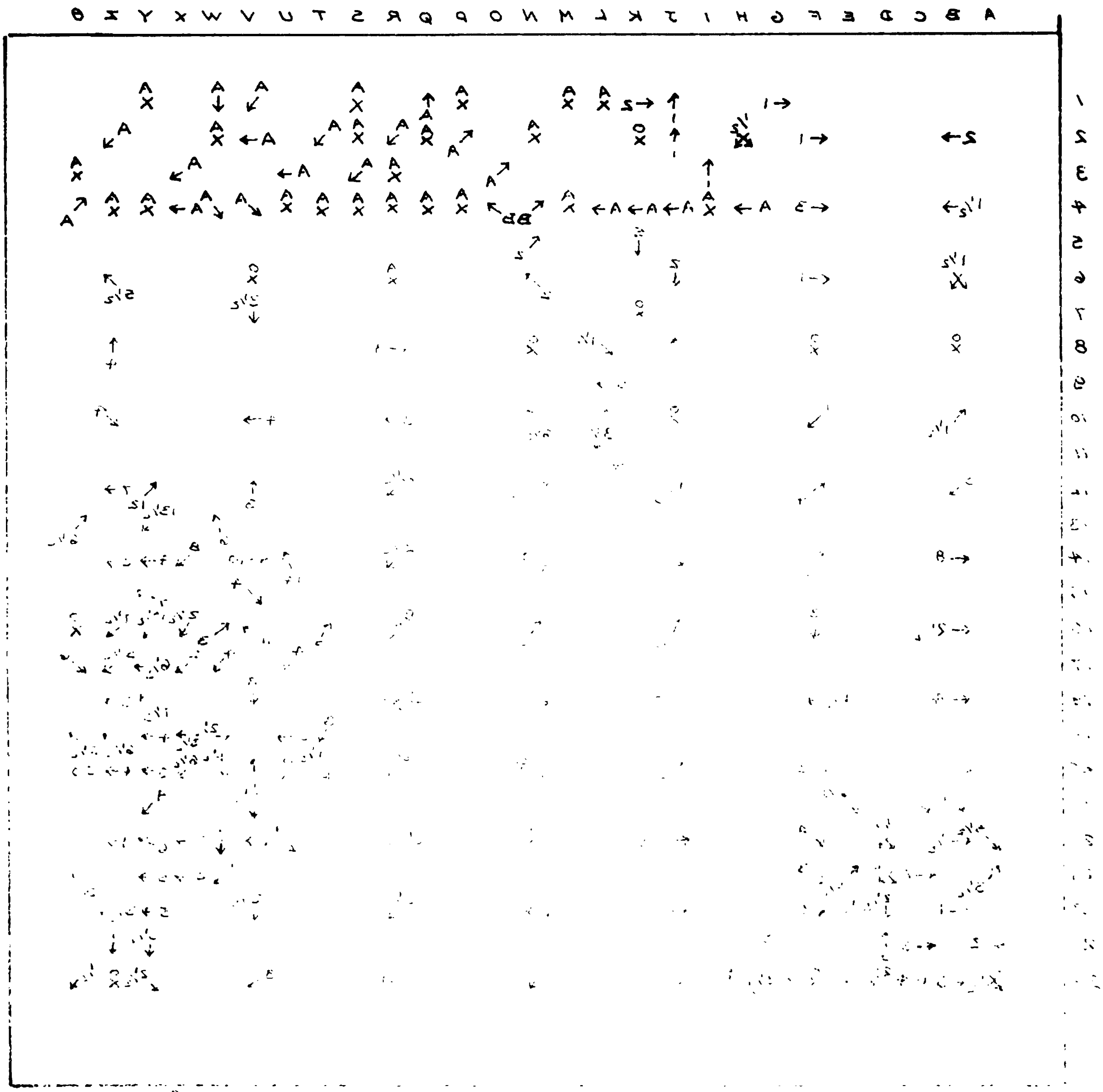


Fig. 15. Slope gradient and aspect at each gridded observation.



Scale
1 inch = 500 feet

delineations.

The incredibly low agreement is startling. Most of the operators had assumed they were performing near the standard of accuracy of 85% homogeneity suggested by the Soil Survey Manual (Soil Survey Staff, 1951, p. 277). Here the situation is reversed, with observations in agreement with the mapping unit comprising a smaller percentage of total observations than the maximum allowable as inclusion. It was a blow to the mappers' credulity as well as their pride. Of course, this analysis excludes all observations other than those of the same taxonomic unit, which means that even differences at the phase of series level were excluded. Thus the same soil type with a different slope or erosion class was treated as an inclusion.

Some explanation should be available for the difference in mapping unit-gridded observation agreement among operators. To seek such a relationship, the parameters of mapping time, traverse distance, number of observations, and number of delineations were plotted as functions of mapping unit-gridded observation agreement. The results of this approach may be seen in Fig. 16.

In each case there seems to be a negative relationship between these parameters and mapping unit-observation agreement. While this relationship is not strong, the trend lines are similar. One might conclude that beyond a certain minimum, increasing mapping time, distance of traverse, number of observations, and number of delineations decreases the accuracy of soil mapping, at least in the case of the operators in this study.

These types of relationship are in direct opposition to the

commonly-voiced opinions among field men who generally believe that increased time and effort will produce a more accurate map, and that accuracy will improve in direct proportion to the time and effort expended. An assumption such as this is intuitively logical, but

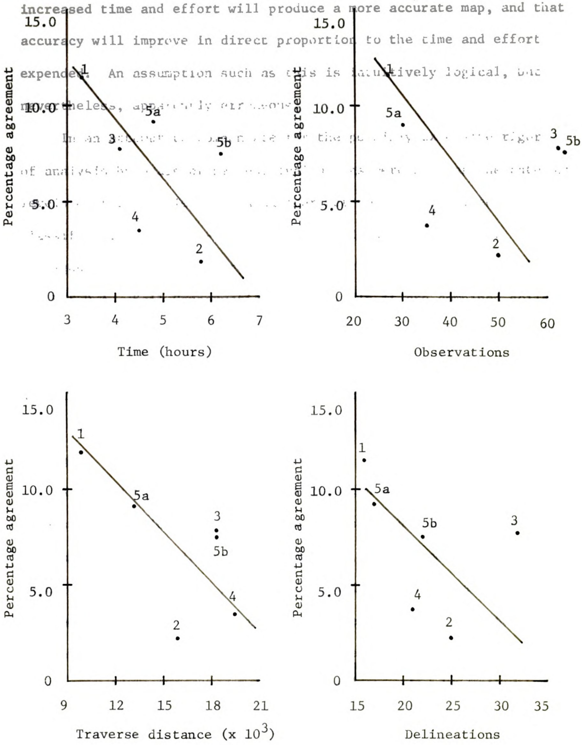


Fig. 16. Mapping unit-gridded observation agreement as a function of time, traverse distance, observations, and delineations.

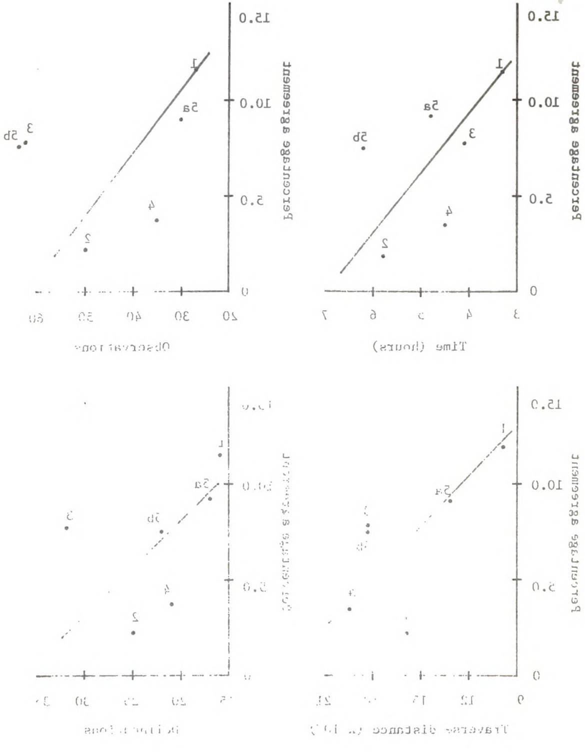


Fig. 16. Mapping unit-gridded observation agreement as a function of time, traverse distance, observations, and inclinations.

commonly-voiced opinions among field men who generally believe that increased time and effort will produce a more accurate map, and that accuracy will improve in direct proportion to the time and effort expended. An assumption such as this is intuitively logical, but nevertheless, apparently erroneous.

In an attempt to compensate for the possibly excessive rigor of analysis by phase of series, evaluations were made at the category levels of type, series, - and another not normally included in classification schemes - the Michigan soil management group. The Michigan soil management group resembles the land capability unit of the U.S.D.A., Soil Conservation Service. In it are combined soils of like potential and behavior. The Michigan soil management group is perhaps more inclusive because it encompasses all surface texture and slope phases of a series, and may include several series. One would think that at this level of generalization most mapping would be highly accurate.

A key to the components of the Michigan soil management groups is given in Table 10. These groups are based on important general characteristics such as stoniness, organic matter content, texture, drainage of the soil profile, and special characteristics such as acidity and cementation. The agreement among operators at the 4 category levels is given in Table 11. Here the agreement percentage for each operator is summed and the mean determined at each category level. In addition, values at each category level are given for five additional maps of the area: the 1933 Ingham County soil survey map; the 1952 detailed soil map of the M.S.U. farm at a 1 inch = 660 feet scale; a modern, large-scale (1 inch = 330 feet) map of the area; and a stereoscopic map of the area (both

Table 10. Key to the components of Michigan soil management groups. (based on profile characteristics to a depth of 3.5 to 5.5 feet)

Important characteristics	Profile texture	Natural drainage	Special characteristics
G - gravelly or stony	0 - fine clay	a - well or moderately-well	a - very acid subsoils
L - lowland or alluvial	1 - clay	b - imperfectly	c - calcareous at surface
M - mucks or peats	1.5 - clay loam	c - poorly or very-poorly	h - subsoils hard or cemented
R - rocky soils (bedrock < 18" deep)	2 - silty clay loam		
M/m 12-42" muck or peat over marl	2.5 - loam		
	3 - sandy loam		
	4 - loamy sand		
	5 - sand		
	4/1 - loamy sand 18-42" over clay		
	5/2 - sand 42-66" over loam or clay		

Table 11. Mapping unit-observation agreement at four category levels.

	Agreement percentage by			
Operator	Phase of series	Type	Series	Management group
1	11.6	20.2	26.1	33.5
2	2.1	6.8	11.1	17.8
3	7.7	15.4	22.1	27.7
4	3.6	8.3	10.4	10.9
5a	9.0	16.0	18.5	21.0
5b	7.5	15.0	21.0	23.0
Σ	41.5	81.7	109.2	133.9
$\bar{x}$	6.9	13.6	18.2	22.3
1933	20.7	21.2	22.2	23.7
1952	2.5	23.1	23.8	30.0
Stereoscopic	2.4	3.8	22.0	25.8
Stereoscopic-adjusted	11.0	19.1	22.0	25.8
1 inch = 330 feet	12.0	18.8	18.8	24.5

unadjusted, and adjusted for the predominant soil type encountered).

It seems that mapping unit-gridding observation agreement should be a function of the mapping experience of the soil surveyor making the map. To test this hypothesis, the relationships between agreement and experience were compared at the 4 category levels mentioned previously. These results are presented in Fig. 17. Apparently no trend exists at the phase and type levels, while only very weak trends are found at series and management group levels. A subject of speculation is whether the relationships would have been stronger with more operators participating in the study. For this study, however, the trend was weak or nonexistent, and the question remaining to be answered is why it was not stronger. This question will be considered in the summarizing discussion.

A question of fundamental importance concerns the progress toward improvement of map detail and accuracy with the progress of soil survey knowledge, technique, and operations. Or, to phrase it another way, are we producing a better product now than we were forty years ago? The answer to this question is illustrated in Fig. 18. This histogram compares 6 mapping approaches at 4 category levels for agreement between mapping units and gridded observations. Because of the broader definition of the mapping units in the 1933 survey, more observations are considered to fall within the range of the mapping unit description, particularly as inclusions. Inclusions of other series are not considered in the 1933 map evaluation unless the series mapped then was partitioned into other series in the interval between the survey publication and the date of this study. For example, the Celina series was partitioned from the Miami series in

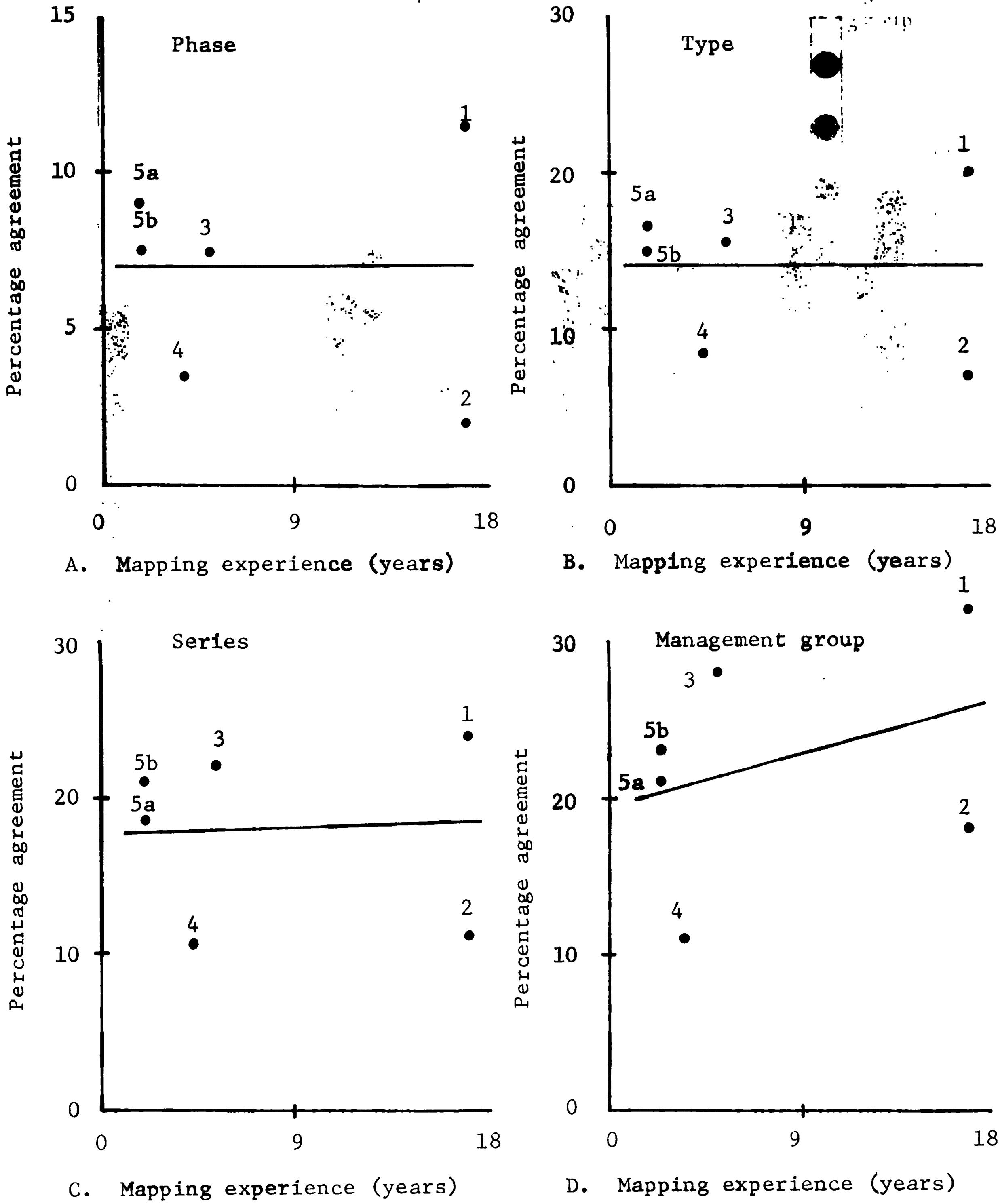


Fig. 17. Mapping unit-gridding observation agreement as a function of mapping experience.

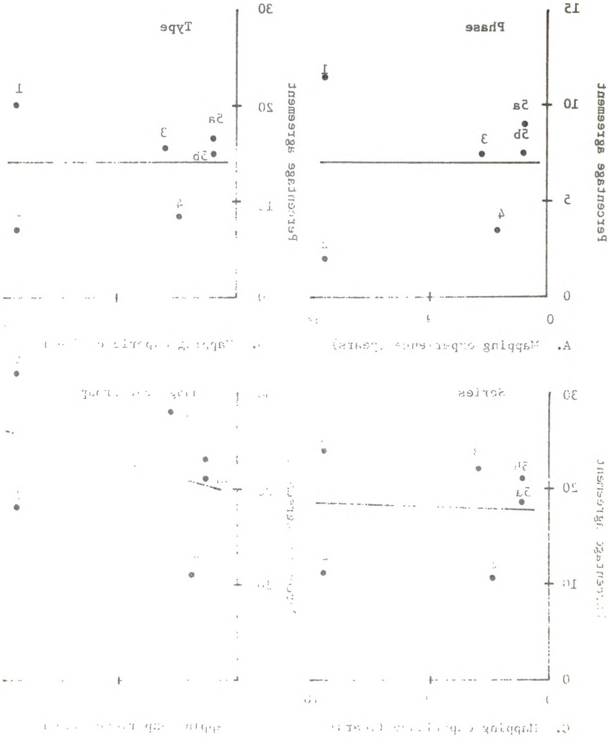

Phase
Type
Series
Percentage agreement
A. Mapping experience (years)
C. Mapping experience (years)

Fig. 17. [illegible]

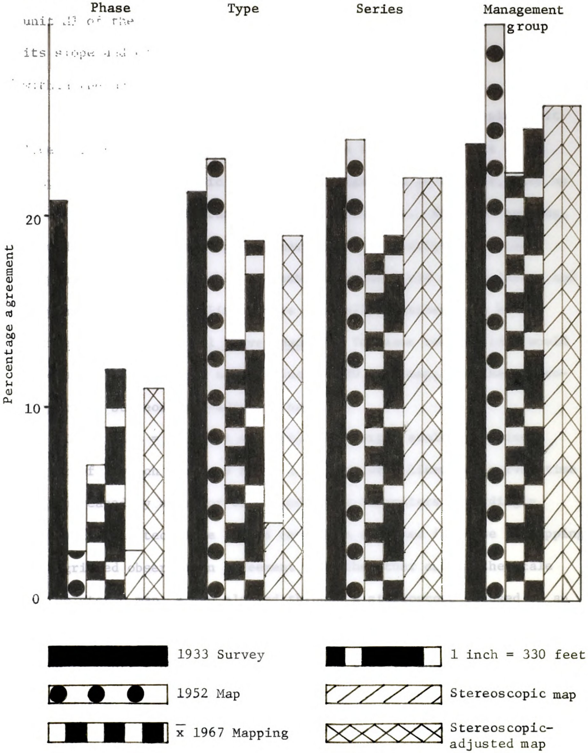
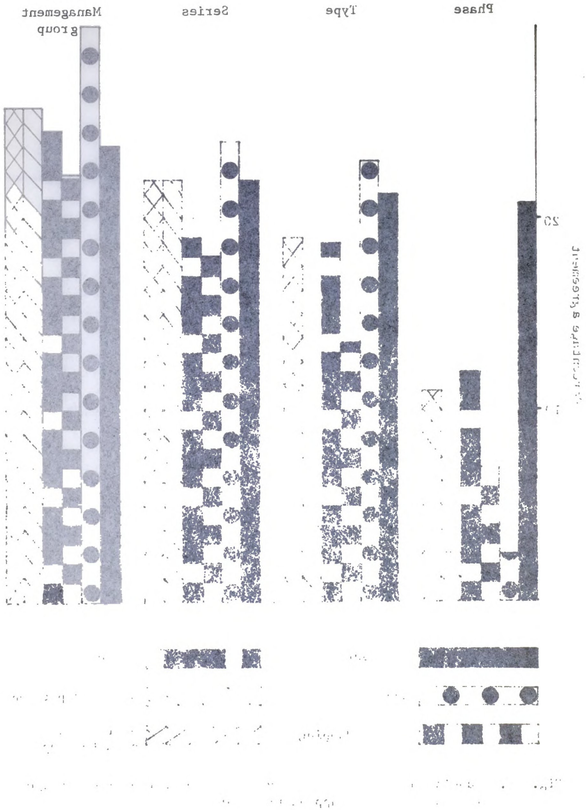


Fig. 18. Mapping unit-gridded observation agreement at four category levels among six mapping procedures.


Phase
Type
Series
Management group
20

1954, which would invalidate exclusion of Celina from the mapping unit M1 of the 1933 survey. Likewise, since M1 included Miami in all its slope and erosion phases, observations of these must be included within the mapping unit range.

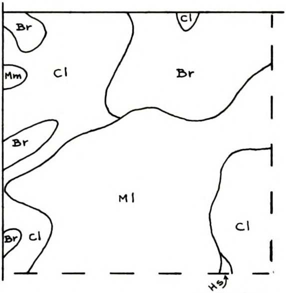
Since no mapping unit description accompanied the mapping unit legend of the 1952 survey, we must assume the mapping units to be composed of the taxonomic unit whose designation it carried, with up to 15 percent of other taxonomic unit inclusions. The 1967 mapping should be judged in the some manner since no description of the mapping units was available to members of the field survey party, and mapping unit inclusion limits were generally considered to be as defined in the 1951 Soil Survey Manual. The same restrictions would also apply to the large scale(1 inch = 330 feet)map, and the stereoscopic and stereoscopic-adjusted map.

The 1 inch = 330 feet map employs a larger scale by a linear factor of 3 which yields 9 as an areal factor. Likewise, survey time was increased by a factor of 4, and other parameters accordingly. Logically this technique should result in a marked increase in mapping unit-gridded observation agreement. On the other end of the scale is the stereo map, a map plotted through a stereoscope focused on an overlapping pair of aerial photographs, both of which included the standard quarter-section. This yields a type of land form map with major topographic features separated from each other by delineation lines. Stereoscoping aerial photographs to delineate major land forms and drainage pattern is recommended by the Soil Survey Manual (Soil Survey Staff, 1951, p. 83). It cautions that the use of the stereoscope without a thorough field check to determine the composition of

the delineated areas can easily lead to serious error. In the present study, the stereoscopic map was made after the completion of the field work. Since taking the map to the field again would have been impractical, the observations of Operator 1, which were used in making his original map of the area, were used to name the stereoscopic delineations. Because these observations were not tailored to the delineations, and because there was no opportunity to adjust these delineations in the field, this map undoubtedly suffered in agreement percentage. For this reason the major delineation was renamed to be in better agreement with the obvious field conditions, and the results of this modification are given under the heading "stereoscopic-adjusted."

The maps under discussion may be observed in Figs. 19 and 20. The 1933 soil map of the area may be compared at its original scale of 1 inch = 1 mile, and expanded to the present Tri-County scale of 1 inch = 1,000 feet in Fig. 19. At the original scale the standard quarter-section was 1/2 inch square or 1/4 square inch, which is very small indeed. This small mapping scale, together with high production quotas, necessitated a high level of generalization. Nevertheless, the agreement between mapping units and gridded observations in Fig. 18 shows this map well ahead of all others at the phase level, a close second at type and series levels, and 79% as good as the best (the 1952 research map) at the management group level. Incidentally, this was still better than the mean of the 1967 mapping, which was only 75% as good as the research map at that level. Apparently, the broader definition of the mapping unit and the broader range of series definition resulted in an increase of only about

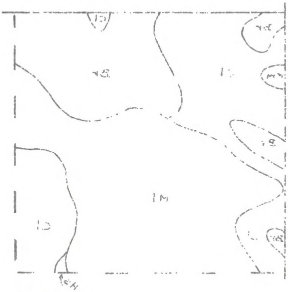
1933 Scale
1 inch = 1 mile



1967 Scale
1 inch = 1000 feet

Fig. 19. 1933 map of standard quarter-section at published and 1967 scale.

1933 Scale
1 inch = 1 mile



1967 Scale
1 inch = 1000 feet

Fig. 19. 1933 Map of a [illegible] quarter-section at published and 1967 scale

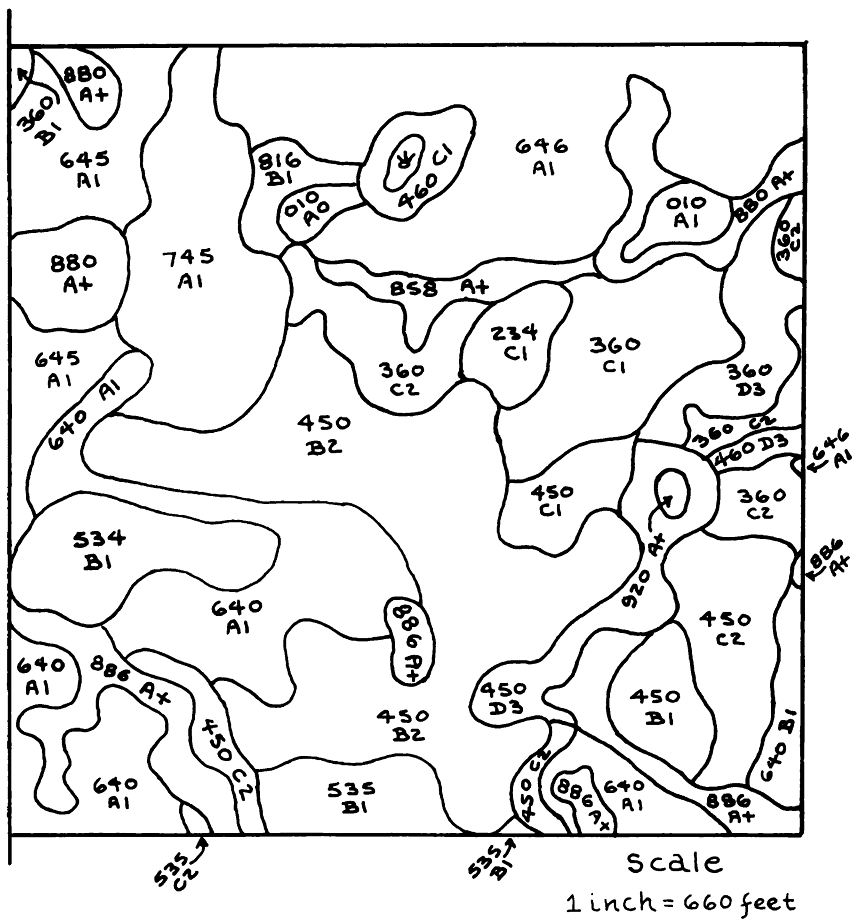
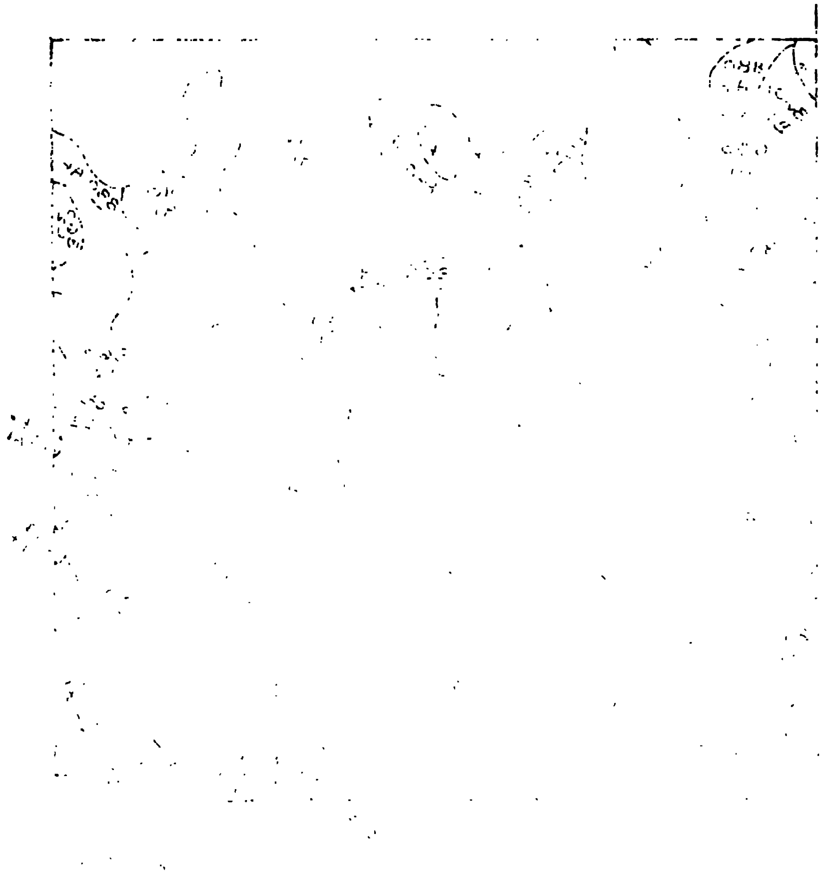


Fig. 20. 1952 research map of standard quarter-section.



13% between phase and management group categories.

The 1952 map was an attempt to make a very detailed soil map for planning of agricultural research projects involving soils. This was made on an aerial photographic base, which was a tremendous improvement over the 1933 plane table sheets in regard to ground orientation and the plotting of delineation lines. The mapping scale was 1 inch = 660 feet, which means the map base area was 64 times that of the 1933 map. We may assume that time was not a limiting factor: it seldom is in cases such as this. Usually as much time is taken as is needed to make what the operator feels is an accurate, detailed map, suitable for research purposes.

This map is shown in Fig. 20. It has 46 delineations as compared to the 10 delineations of the 1933 map. An increase in the number of delineations seems to be a natural result of increasing mapping scale, whether the purpose of the map is for soil research or not. When evaluated for mapping unit-gridded observation agreement at the phase level (Fig. 18), this map rated very low, almost as low as the stereoscopic map. At the type, series, and management group levels it rated highest, however, even above the 1 inch = 330 foot map. Although the 1952 map achieved greater agreement at these levels than the mean of the 1967 mapping (Table 11), it was not much higher than Operator 1 at the type level, Operators 3 and 5b at the series level, and Operator 5b at the management group level. It was lower than Operator 1 at series and management group levels.

To study the effect of mapping scale and survey time on mapping accuracy, a map was made of the standard quarter section at a scale of 1 inch = 330 feet. This is larger than 1967 mapping scale by a linear

factor of 3 and an areal factor of 9. This particular scale was chosen as a reasonable limit in mapping scale at the level of technology at the time of this study. Enlargements at the 1 inch = 330 foot scale, along with prints of the area at other scales, were procured from the Abrams Aerial Survey Corporation in Lansing, Michigan. The laboratory supervisor at Abrams assured the author that enlargement at any scale greater than 1 inch = 330 feet would produce serious loss of resolution in the resulting print.[1] In addition, the 1 inch = 330 foot scale approached the 1 inch = 200 scale which was being used at this time as a base for the survey in MacComb County, Michigan, just west of Detroit. However, in the MacComb County survey, mapping time, or production, was expected to equal other soil surveys being made on a standard photographic base of 1 inch = 1,320 feet. Therefore, soil surveyors working in MacComb County were instructed to ignore delineations the size of a half-dollar or smaller.[2]

The author was strongly convinced from personal experience that an increase in mapping scale would normally result in a longer period of time required to make a soil map. Primarily this is caused by the surveyor being able to recognize more land features on the photograph, and having more room to record delineations and symbols on the map. If the surveyor is conscientious, sees more features, and has more room to record them, he will record them. This requires more time and results in decreased mapping production. But the logical result of

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[1]Personal communication from Paul R. Hodges, Laboratory Supervisor, Abrams Aerial Survey Corporation, Lansing, Michigan.

[2]Personal communication from Glenn Bedell, former Party Chief, Tri-County soil survey, U.S.D.A., Soil Conservation Service.

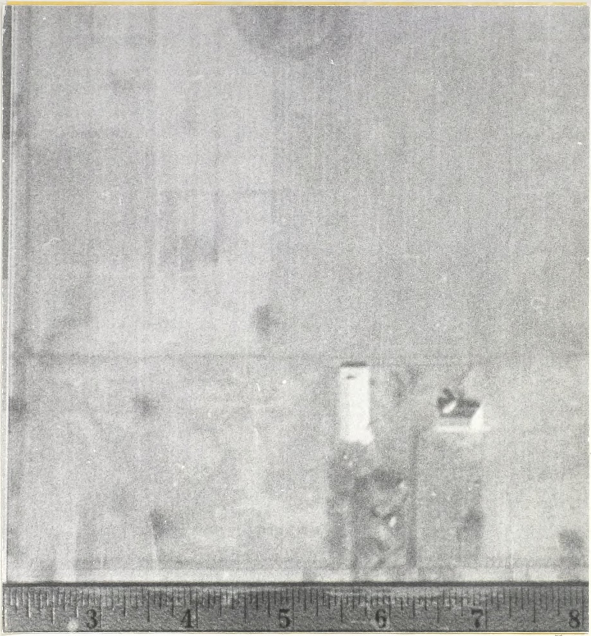
increasing scale and allowing more mapping time should be more soil separations (or more delineations), more accurate delineations, and consequently, a more accurate map.

A comparison of the same area on aerial photographs enlarged to two different mapping scales - 1 inch = 1,320 feet and 1 inch = 200 feet, the minimum and maximum scales used in part C of this section - is shown in Fig. 21. The difference in recognizable ground detail is striking, as well as the space available for delineations and mapping unit symbols. In planning his technique for making the 1 inch = 330 foot map, the author decided to be governed by perceptible ground detail at the enlarged scale, making the observations necessitated by this detail. The parameter left unrestricted was survey time.

The map resulting from this approach is shown in Fig. 22. It required 11 hours and 10 minutes to make. A total of 93 observations yielded a map with 39 delineations. Mapping production at this rate would have been about 100 acres per day rather than the 320 acres per day required at the normal mapping rate. If this had resulted in marked increase in accuracy - a much better map - it could have been economical in the long run.

Again the results given in the histogram in Fig. 18 are surprising. Agreement between mapping units and gridded observations failed to prove this map superior to all other mapping at any category level. It was superior to the mean of the 1967 mapping, but only notably so at the phase and type levels. It fell below the 1952 map at type, series, and management group levels, although it was obviously superior at the phase level. Perhaps the most revealing comparison is with the 1967 map made by Operator 1, which is a comparison of mapping at

Scale
1 inch = 1320 feet



Scale
1 inch = 200 feet

Fig. 21. Aerial photographs of 1/16 of a section (40 acres) at two scales.

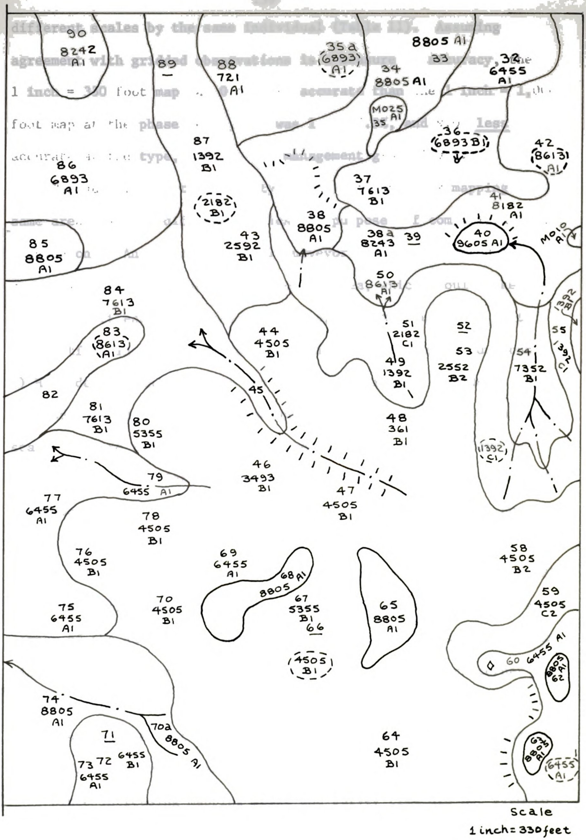
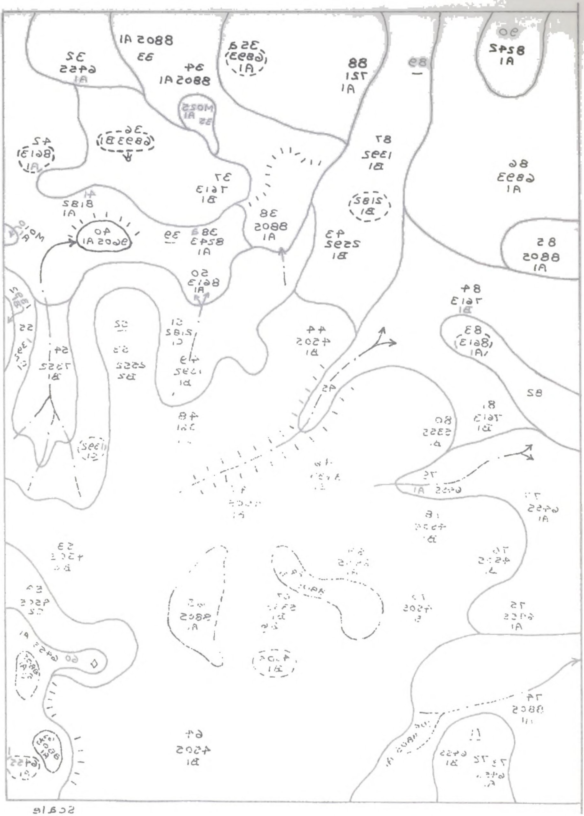


Fig. 22. Western 70% of standard quarter-section mapped at 16 inches = 1 mile.



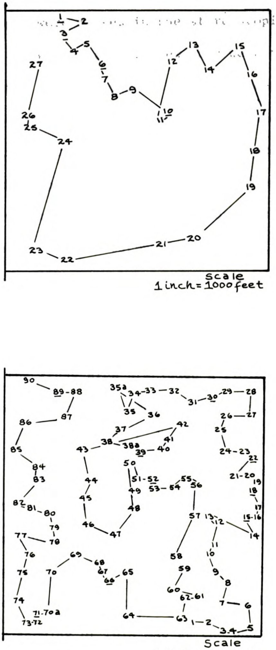
Scale
1 inch = 330 feet

different scales by the same individual (Table 11). Assuming agreement with gridded observations is a measure of accuracy, the 1 inch = 330 foot map was 0.4% more accurate than the 1 inch = 1,000 foot map at the phase level, but was 1.4%, 7.3%, and 9.0% less accurate at the type, series, and management group level.

The question of the validity of one soil surveyor mapping the same area twice at different scales for purposes of comparison is a nagging one. An experienced soil surveyor would be expected to retain some residual knowledge about an area, which should make the second effort easier and the results superior to the first. With this pitfall in mind, Operator 1 exercised the following cautions: 1) He made the smaller-scale map first, assuming any residual knowledge would tend to be redundant in the second effort at a larger scale and more intensive study; 2) he made a conscious effort to forget the first effort as soon as it was completed and to block off any memories of it while he was making the larger scale map; and 3) he attempted to walk a different transect pattern at the different scales. A comparison of these transect patterns is given in Fig. 23. At the smaller scale, the transect pattern begins at the northwestern corner of the quarter-section, and the direction is basically clockwise. At the larger scale, it begins at the southeastern corner and is counter-clockwise for the first half of the map, but returns to clockwise for the last half. Less than half of the general pattern of the first is duplicated by the second.

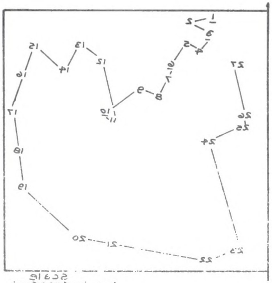
Since increasing mapping scale and survey time did not seem to yield significant advantages, the next approach was an attempt to determine the least amount of time required to map this area without

sacrificing map quality. For this a stereoscopic map was constructed (Fig. 24). This map shows a number of land forms which are readily observable [illegible] should be separated. Several [illegible] process, [illegible] when he [illegible]

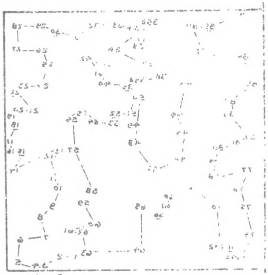


(Reduced to 1/9 original size for comparison)

Fig. 23. Transect patterns of Operator No. 1 while mapping standard quarter-section at different scales.



Scale
1 in. = 1000 feet



Scale
1 inch = 330 feet
(Reduced to 1/2 original size
for comparison)

Fig. 23 Transect patterns of Operator no. 1 while mapping
transects of vegetation at different scales.

sacrificing map quality. For this a stereoscopic map was constructed (Fig. 24). This map shows a number of land forms which are readily observable in the field, and which should be separated. Several important slope changes were missed in the stereoscopic process, however. And, even though the author knew they were there when he was peering through the stereoscope, he could not see them. Steeper slopes encompass the drain running to the north in the western one-third of the map. In addition, there is a steeper area around the central portion of the map, approaching the eastern edge.

Since this map was made after the field work was completed, a cardinal rule in the use of stereoscopy in soil mapping was violated. A stereoscopic map should always be checked in the field for accuracy of delineation lines, modified where necessary, and the soil examined before the mapping unit is recorded in the delineations. In this case, since distance from the study area precluded a field check, the author chose the observations recorded by Operator 1 (himself) in making the 1 inch = 1,000 foot map to serve as bases for naming the delineations on the stereo map. Therefore, the delineations which contain no observations are not given mapping unit names. Since these delineations could neither add to nor detract from the agreement percentage analysis, agreement should have been unaffected.

Agreement percentages can be compared in Fig. 18. One notes immediately the poor showing of this map at the phase and type levels, while the agreement at series and management group levels was quite respectable. Poor showing in the lower categories probably resulted from lack of normal field checking. Better showing at higher levels

must be due to decreased emphasis on surface texture and slope at those levels.

One of the biggest errors was in identifying delineation no. 2 as 4503/B1, Miami sandy loam (2-6% slopes). An experienced mapper might have [illegible] this [illegible] because this delineation [illegible]. And from [illegible]

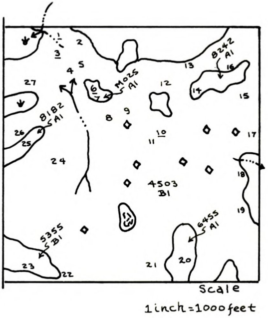
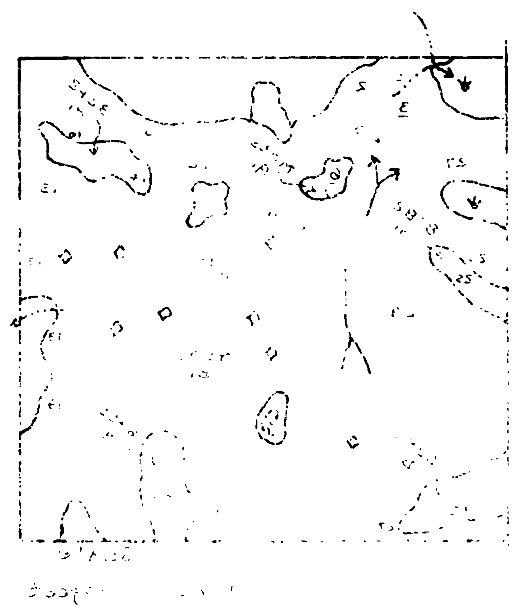


Fig. 24. Stereoscopic map of standard quarter-section with observations of Operator No. 1 (1 inch = 1000 foot map) superimposed.



must be due to decreased emphasis on surface texture and slope at those levels.

One of the biggest errors was in identifying delineation no. 2 as 4503/B1, Miami sandy loam (2-6% slopes). An experienced mapper might have reached such a conclusion in the field, because this delineation did contain a sizeable sandy surface component. And from the observations lying within this delineation, no other call was possible. However, by making only one modification - by changing the surface texture of delineation no. 2 to a loam - the agreement indicated in Fig. 18 (stereoscopic-adjusted) is competitive with the other maps at all levels. How much better the stereoscopic map would have scored with a field check is open to conjecture. With minor modifications it might have improved, as in the previous example. Major modification might have caused it to fare more poorly, however. As it was, the performance was surprisingly good.

The discussion in the previous several pages has centered around relative agreement among maps of a standard quarter-section - produced by various members of the contemporary National Cooperative Soil Survey, maps produced in surveys of other eras, and maps produced in special surveys - with gridded, recorded observations of the area. In addition, the contemporary maps have been evaluated for the relationship between mapping unit-delineation agreement and number of delineations, number of borings, time required to make the map, and traverse distance. Since there appeared to be so much variation among the maps in Fig. 12, it seemed advisable to make a comparison of the treatment of the soils of the Miami catena by the operators from the contemporary soil survey.

Soils of the Miami catena are some of the best known and most widely distributed in the Lower Peninsula of Michigan. According to the 1933 Ingham County survey, these soils comprise 145,280 of the 353,920 acres in Ingham County, or 41% of the total area (Veatch et al., 1941, p. 14). They serve as the bench marks against which many other series are compared. Derived from a single parent material, the widely distributed loamy till, they are among the most straightforward of all series in concept. They are valued as agricultural soils and much sought after by farmers. In short, of all the Southern Michigan soils, those of the Miami catena are the most important.

In Fig. 25, variations in the way the operators mapped the soils of the Miami catena may be observed. Obviously, there is a great discrepancy among operators as to the extent of the catena present in the quarter-section. Three operators - 1, 3, and 5 - allocate more than half the area to this catena. Operators 2 and 4 consider it to be much less extensive. Operator bias according to series is also apparent - Miami is a great favorite of Operator 1; Operators 2 and 5 favor Conover, as does Operator 3, but he likes to cut it up into small delineations. Operator 3 also maps the largest area of Celina, and in so doing emphasizes a difference in concept with Operator 1, who has mapped Miami in the same area. Operator 5 is the only mapper who delineates Brookston, and he reiterates his spring findings in the fall, although by this time it has shrunken somewhat in size, and significant areas have migrated toward the eastern boundary of the quarter-section.

The extent of these units mapped by the various operators is summarized in Table 12. They are expressed as areal percentages of the

Soils of the Bland series are some of the best known and most widely distributed in ... counties. ... the 1933 inquest ... 255.

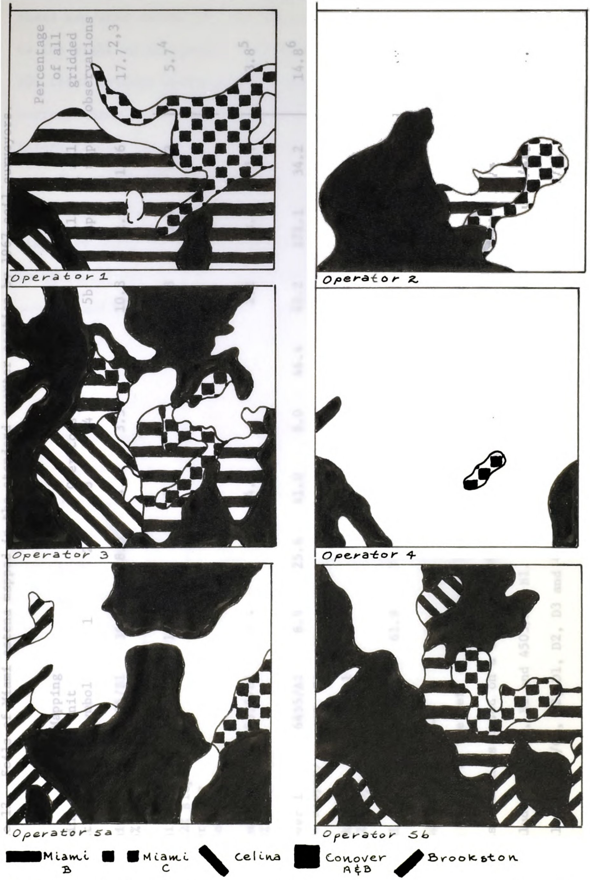


Fig. 25. Distribution of Miami catena soils among 1967 soil maps of standard quarter-section.

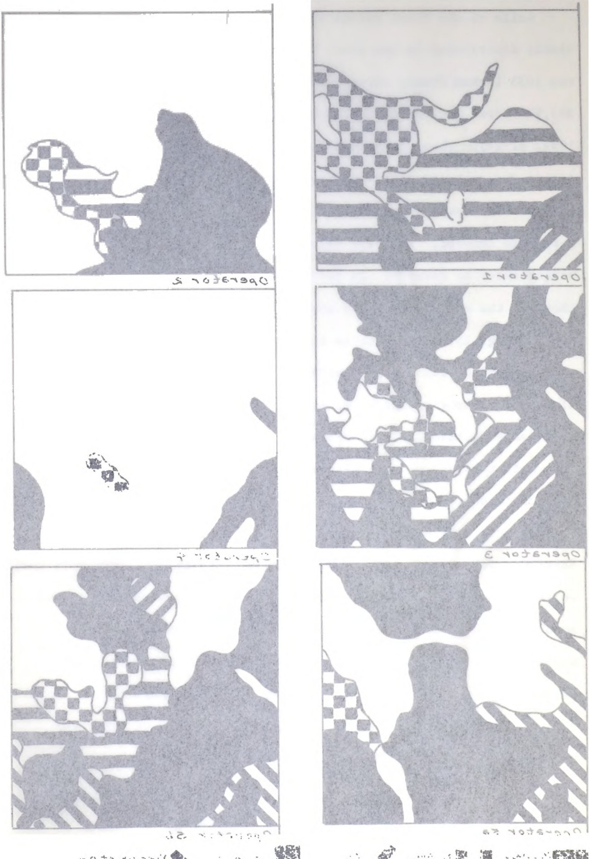

Operator 1
Operator 2
Operator 3
Operator 4
Operator 5a
Operator 5b

Table 12. Soils of Miami catena mapped in the standard quarter-section by 1967 soil surveyors.

Mapping unit	Mapping unit symbol	Operators 1	2	3	4	5a	5b	Σ all maps	$\bar{x}$ All maps	Percentage of all gridded observations
Miami 1 (2-6% slopes)	4505/B1	36.6[1]	8.0	14.0	3.5		10.8	72.9	14.6	17.7[2,3]
Miami 1 (6-12% slopes moderately eroded)	4505/C2	16.0		5.2		3.9	6.3	31.4	6.3	5.7[4]
Celina 1 (2-6% slopes)	5355/B1	2.4		14.0			2.2	18.6	3.7	3.8[5]
Conover 1 (0-6% slopes)	6455/A1 & B1	6.9	25.6	41.0	8.0	46.4	43.2	171.1	34.2	14.8[6]
Brookston 1 (0-2% slopes)	8805/A1					10.0	7.6	17.6	3.5	11.0[7]
Total		61.9	33.6	74.2	11.5	60.3	70.1	311.6	62.3	53.0

[1]All values to the left of the dashed line are based on areal percentages.

[2]This column is based on a total of 209 gridded observations.

[3]Includes 4505/A1, B1 and 4503/A1, B1.

[4]Includes 4505/C1, C2, D1, D2, D3 and 4503/C1.

[5]Includes 5355/A1, B1, C1.

[6]Includes 6455/A1, B1, B2, C1.

[7]Includes 8805/A1, B1.

total map area except for the summary and mean columns, and the column to the right of the dashed line which is a percentage value based on 209 total gridded observations. These values include all observations corresponding to the mapping unit as well as other closely related observations.

The areal relationship of Miami catena soils among maps of different operators is plotted in Fig. 26. This emphasizes the disparity among the soil surveyors participating in this study as to the total percentage of the Miami catena in the standard quarter-section and the relative percentages of its component soils.

The data and analyses in this section seem to point strongly to three major conclusions:

1. Soil mapping is a subjective art and varies greatly among individuals.
2. Increasing mapping time and scale does not increase mapping accuracy.
3. A general map with broad mapping unit definitions is more accurate than an intensive map with narrow mapping unit definitions.

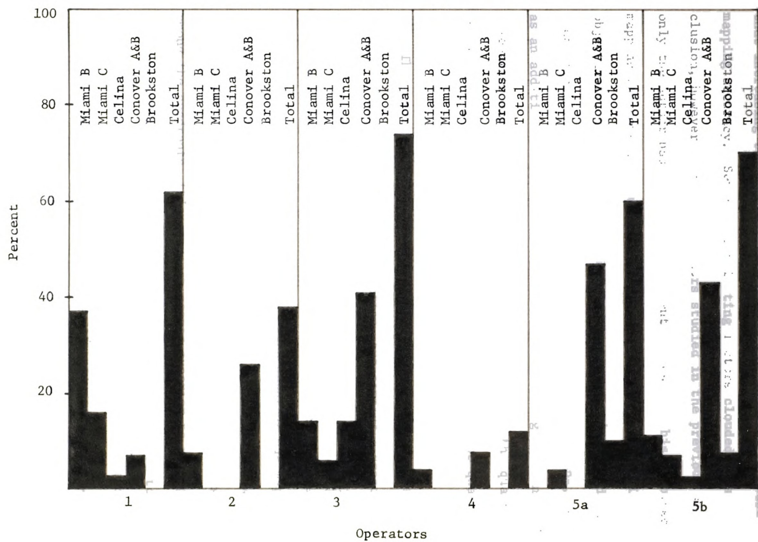
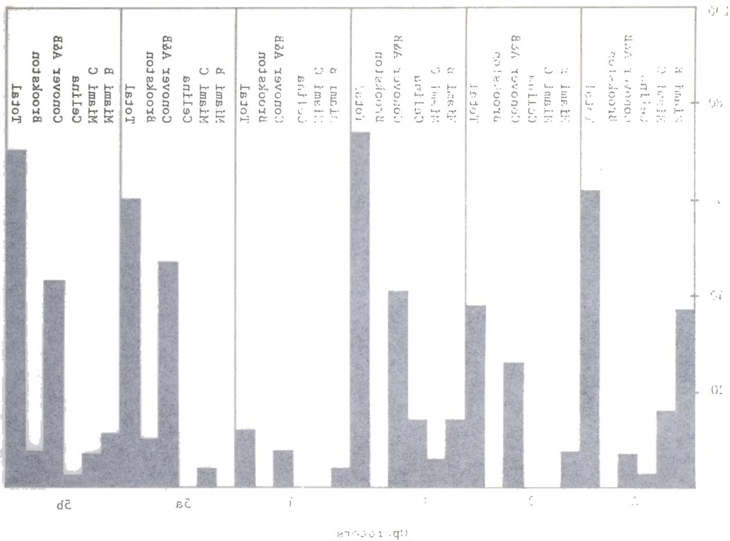


Fig. 26. Soils of the Miami toposequence as mapped in the standard quarter-section by various operators.



... standard quarter-section by various operators.

C. EFFECT OF MAPPING SCALE ON MAP ACCURACY

In the previous section the author was forced to the conclusion that increasing the mapping scale does not necessarily increase mapping accuracy. Several complicating factors clouded this conclusion, however. Of the operators studied in the previous section, only the author had mapped at different scales and this involved mapping the same area twice. Despite his efforts to maintain objectivity, there was always the chance the author's second map had been compromised by previous experience. For these reasons, and to serve as an additional check on what seemed to be an illogical conclusion, a separate mapping scale experiment was designed for the quarter-section lying contiguous to the southern boundary of the quarter-section used in the previous study.

This quarter section had been evaluated in a cursory manner as similar to the standard quarter-section, but simpler - especially since there seemed to be more loam and less sandy material lying on the ridges and along drainageways. This quarter section was divided into four quadrants of 40 acres each. Each quadrant was mapped at a different scale: 1 inch = 1,320, 660, 330, and 200 feet. While there seemed to be some discrepancies in topographic complexity among the quadrants, this approach seemed superior to remapping the same area several times. In addition, the results seemed to substantiate one point: that increasing the mapping scale does not <u>necessarily</u> result in a greater number of soil delineations.

Fig. 27 illustrates the variation in mapping scale used in this study. The northwestern quadrant was assigned the contemporary National Cooperative Soil Survey mapping scale of 1 inch = 1,320 feet,

and the remaining quadrants were assigned progressively larger scales in a clockwise direction. The 1 inch = 330 foot quadrant was the least complex topographically, while the 1 inch = 200 foot quadrant was the most complex.

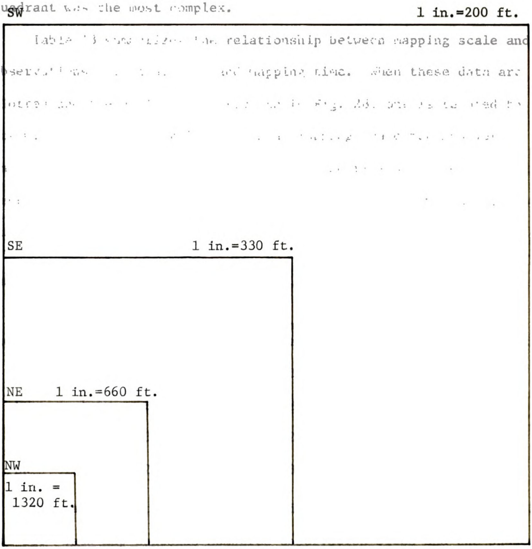


Fig. 27. A comparison of scales used in 40-acre quadrant mapping.

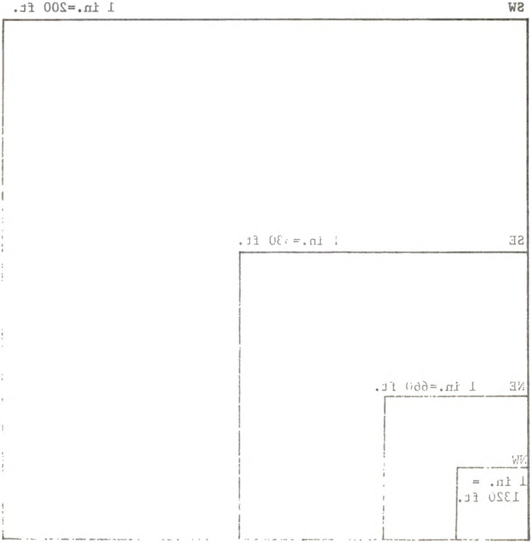


Fig. 27. A comparison of scales used in 40-acre quadrant mapping.

and the remaining quadrants were assigned progressively larger scales in a clockwise direction. The 1 inch = 330 foot quadrant was the least complex topographically, while the 1 inch = 200 foot quadrant was the most complex.

Table 13 summarizes the relationship between mapping scale and observations, delineations, and mapping time. When these data are plotted and trend lines are drawn as in Fig. 28, one is tempted to toy with a geometeric relationship as mapping scale becomes very large. The dip at 1 inch = 330 feet and the rise at 1 inch = 200 feet probably only reflect variation in topographic complexity, however.

Table 13. Mapping time, observations, and delineations as related to mapping scale.

Quadrant	Scale	Mapping time	Observations	Delineations
NW	1 in. = 1,320 ft.	2 hrs. 30 min.	20	8
NE	1 in. = 660 ft.	3 hrs. 8 min.	25	12
SE	1 in. = 330 ft.	2 hrs. 20 min.	21	7
SW	1 in. = 200 ft.	4 hrs. 30 min.	40	17

The maps resulting from this study are shown in Figs. 29, 30, 31, and 32. Each map contains numbered observation sites and the phase of series designation at each site; the delineation designation; special feature symbols (Soil Survey Staff, 1951, plates 1-7); delineation lines and drainage lines; and encircled delineation numbers. The composite map (Fig. 33) gives the location of each gridded observation point, which is designated by a small circle, and the taxonomic designation of each point.

In the first quadrant map at 1 inch = 1,320 feet (Fig. 29),

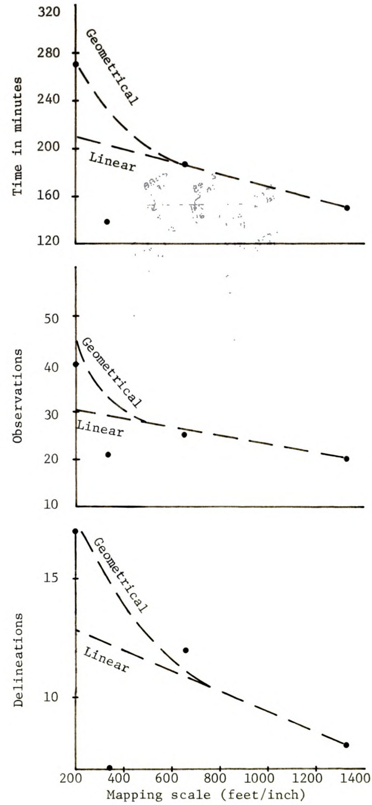


Fig. 28. Trends of mapping time, observations, and delineations with mapping scale.

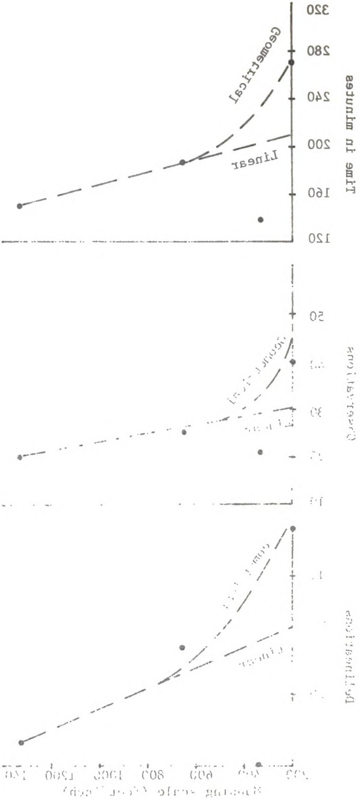
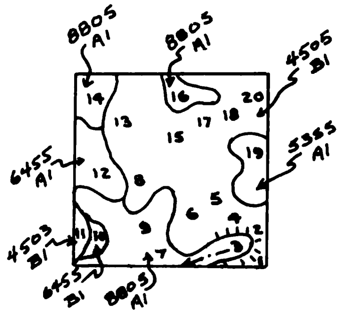


Fig. 28. Trends of mapping time, observations, and delineations with mapping scale

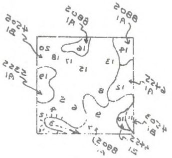


Scale
1 inch = 1320 feet

Observations

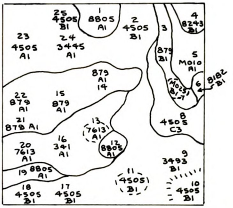
1	2592/B1	11	4503/B1
2	3603/B1	12	6455/A1
3	8817/A1	13	4503/B1
4	4503/B1	14	8805/A1
5	4503/B1	15	4505/B1
6	4503/B1	16	8805/A1
7	8805/A1	17	4505/B1
8	4505/B1	18	6455/A1
9	8805/A1	19	5355/A1
10	6455/B1	20	4505/B1

Fig. 29. Soil map of NW 1/4, SW 1/4, Section 31, Meridian Township.



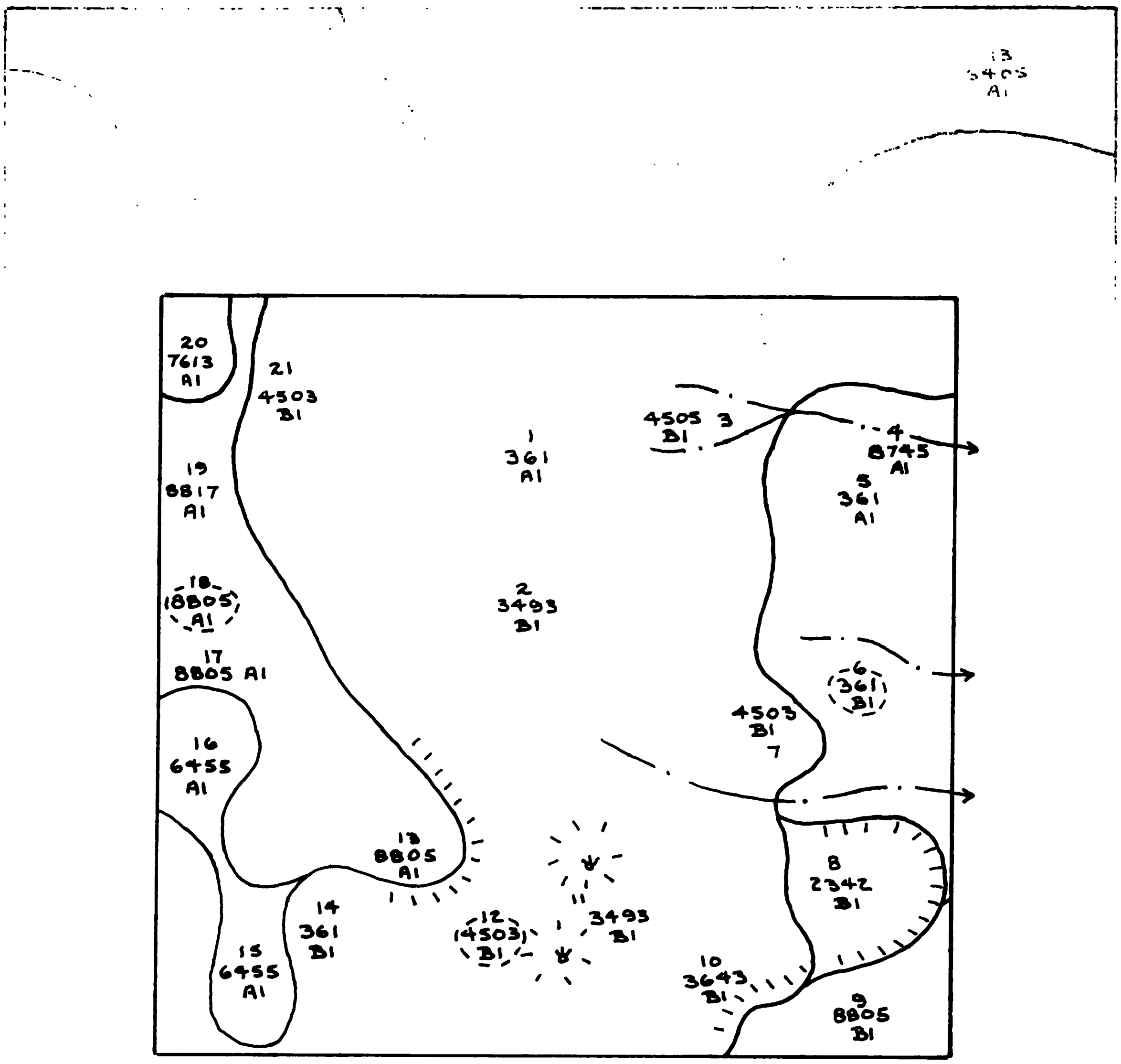
Observations

Fig 25.



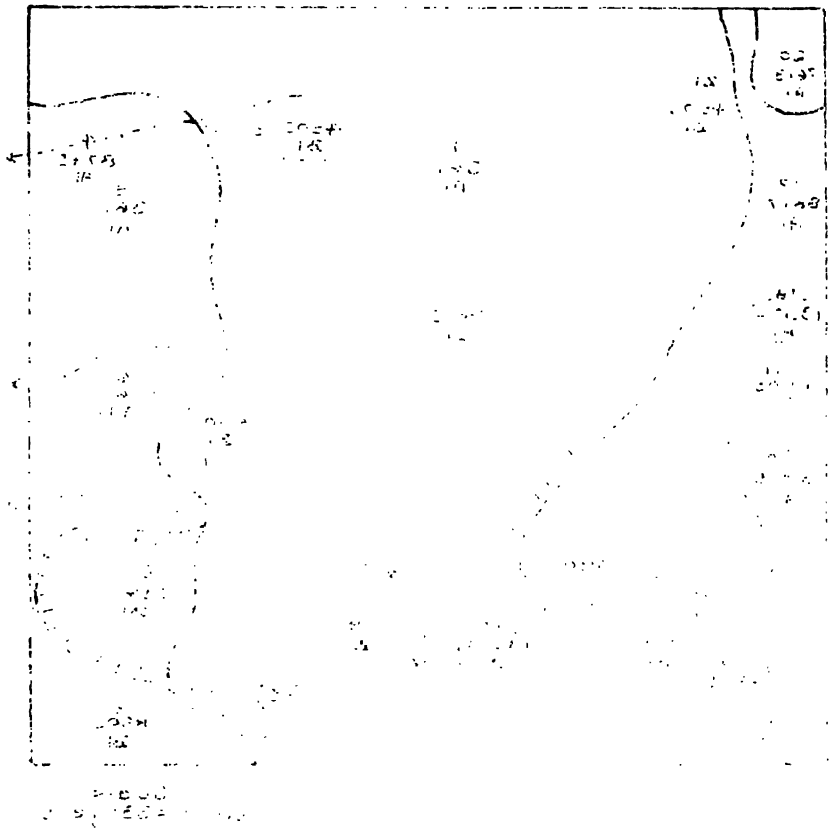
Scale
1 inch = 660 feet

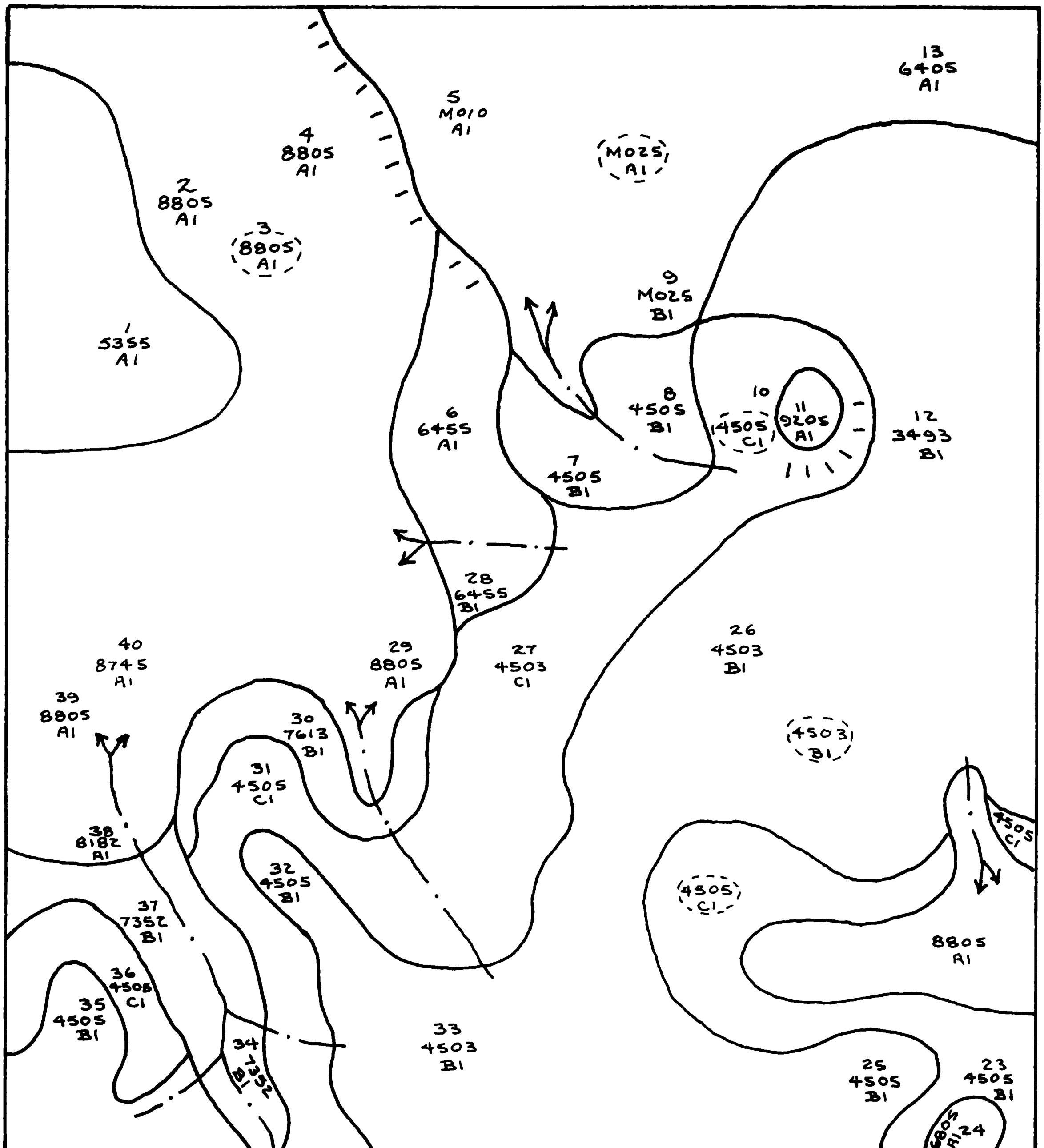
Fig. 30. Soil map of NE 1/4, SW 1/4, Section 31, Meridian Township.



Scale
1inch=330feet

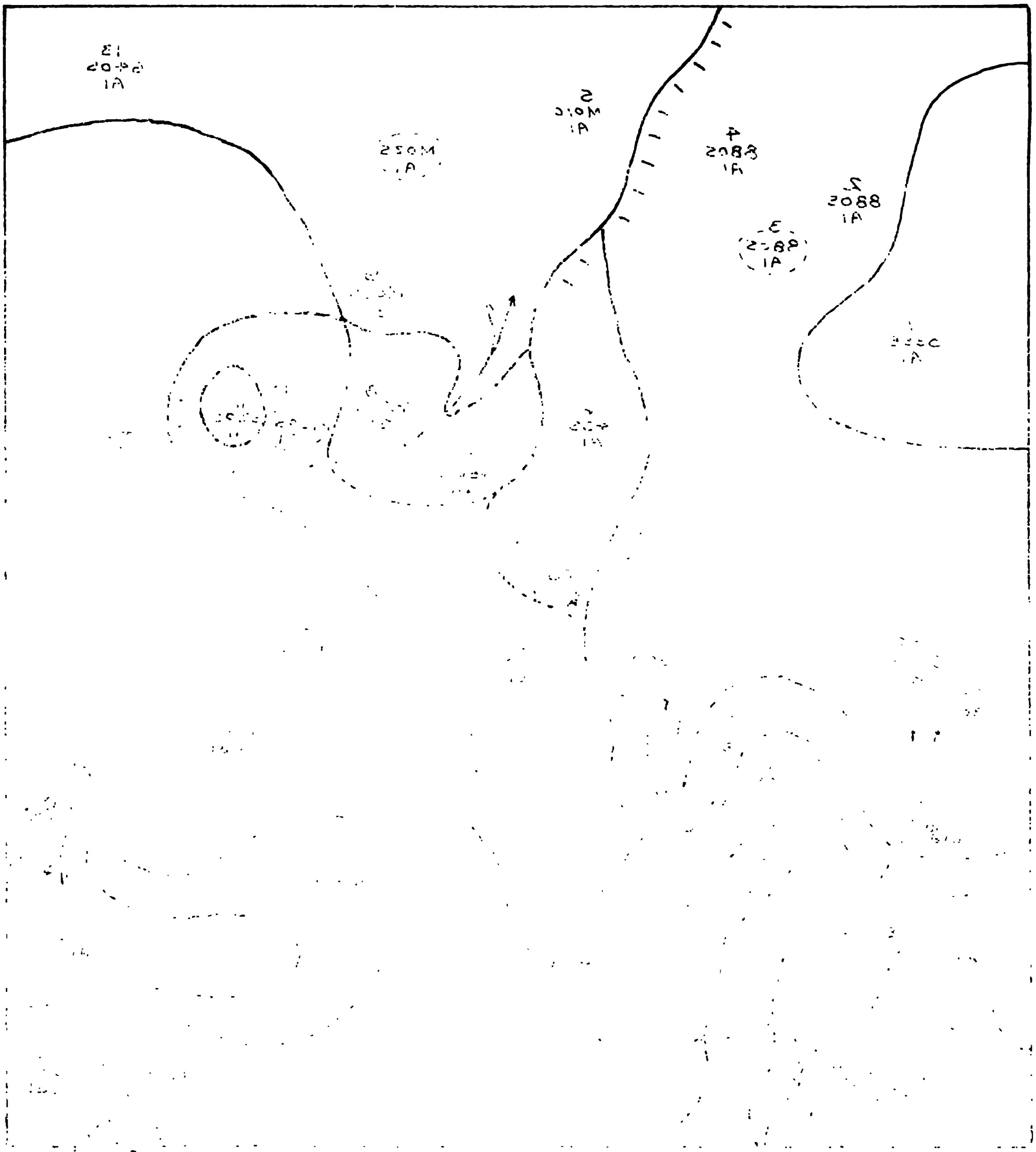
Fig. 31. Soil map of SE 1/4, SW 1/4, Section 31, Meridian Township





Scale
1inch= 200feet

Fig. 32. Soil map of SW¼, SW¼, Section 31, Meridian Township (western 85%).



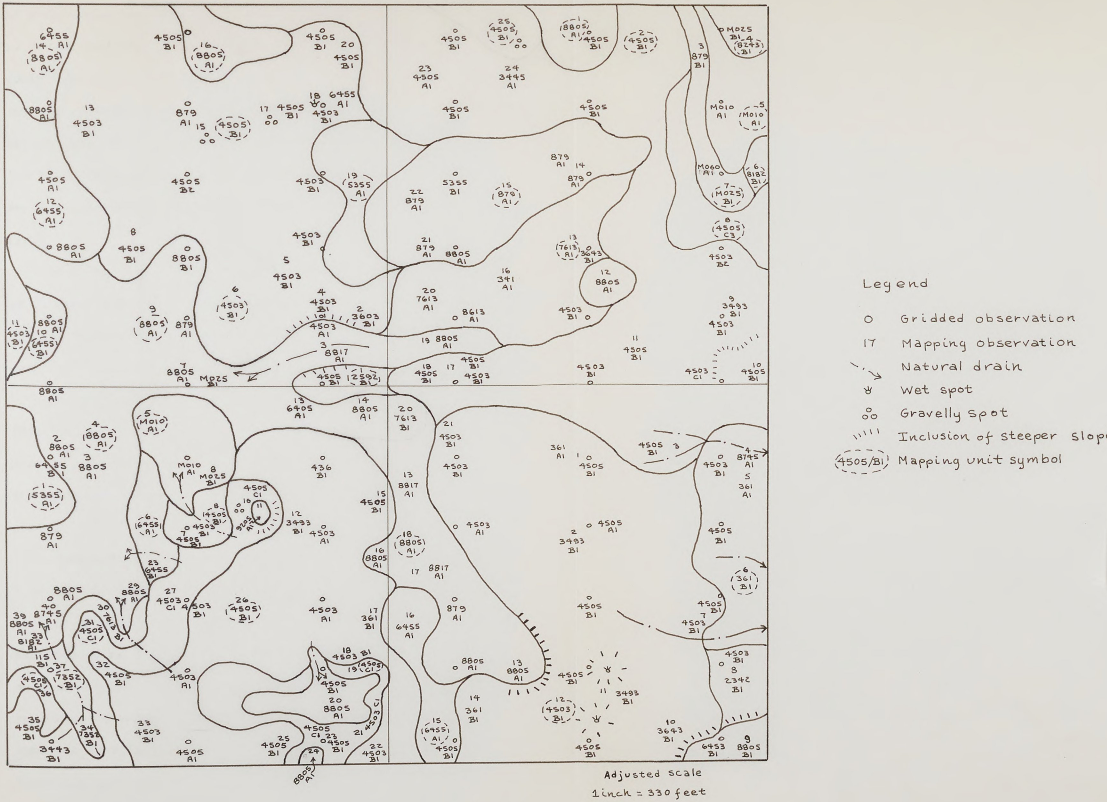


Fig. 33. Composite soil map of SW 1/4, Section 31, Meridian Township.

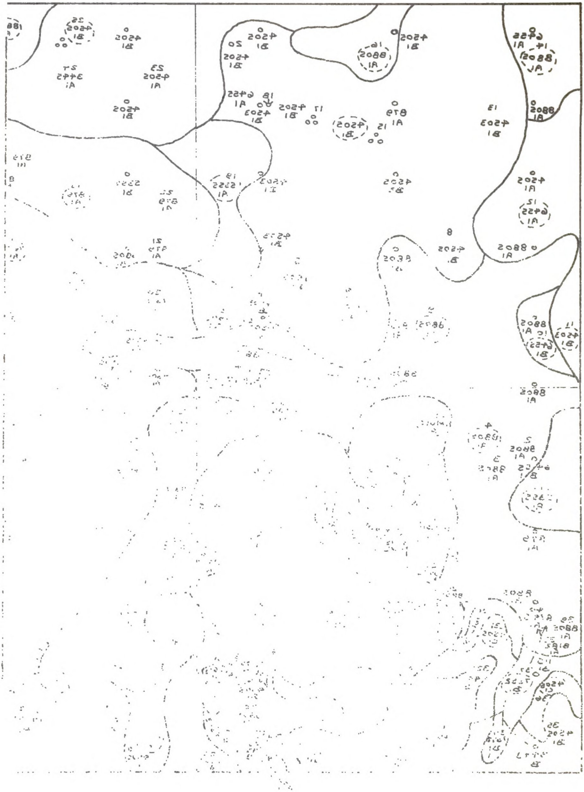


Fig. 53

if observation numbers and delineation numbers - which are extraneous to normal mapping - were removed, then perhaps only one delineation would have to be deleted, assuming the others extended significantly into the contiguous areas. If the delineations did not significantly expand into other areas then 3 more would have to be deleted, leaving 4 delineations in all. Were they approximately equal in size, possibly 5 or 6 delineations would be normal in a complicated area.

Doubling the scale produced the map shown in Fig. 30 at a scale of 1 inch = 660 feet. Here there is adequate room for 11 delineations, 25 observations, and special symbols. Only one delineation is too small to be practical, although one other delineation is marginal.

In contrast, doubling the scale again to 1 inch = 330 feet (Fig. 31) results in a map with delineations unnecessarily large in a relatively simple soil area. With so much room for only 7 delineations, the mapper finds himself feeling guilty about wasting paper.

Upon moving to a more complicated area (Fig. 32), a scale of 1 inch = 200 feet allows 17 delineations to be shown with still a feeling of unnecessary map-base area. When compared to the same map reduced to a 1 inch = 330 foot scale, as in the southwestern quadrant of the composite map in Fig. 33, it is obvious that a reduction to about 60 percent of the original scale has caused no apparent loss in detail. It is apparent, however, that further reduction in scale would cause the loss of several delineations.

The composite map shown in Fig. 33 is a map of the entire

quarter-section with the 1 inch = 1,320 and 660 foot maps expanded and the 1 inch = 200 foot map reduced to give a map with a uniform 1 inch = 330 foot scale. It was necessary to make certain adjustments in delineation lines across boundaries since the quadrants were mapped independently with a conscious effort not to concentrate on the nature of soil across the boundary of a previously mapped quadrant. Matching delineation lines across map boundaries is a common practice among soil surveyors in field mapping operations. It allows maps to join with agreement across boundaries, and is supposed to provide exchange in concepts of soil individuals between mappers (Soil Survey Staff, 1951, pp. 118-119). Often it results in field sheets being mapped in greater detail along match lines than within their interior.

A brief inspection of this composite map reveals no apparent unnecessary detail along match lines, or particular decrease in detail toward map centers. In fact, the map seems to have good continuity of detail among all its quadrants. Although there is greater detail in the southwestern quadrant and less in the southeastern quadrant, this seems more related to land form configuration than mapping scale.

The summation of this phase of the study is presented in Fig. 34. Here percentage of mapping unit - gridded observation agreement is plotted against mapping scale at three levels of classification. The gridded observations serving as a standard of evaluation are shown on the composite map in Fig. 33. Observations were made at 250 foot intervals along 450 foot transects. These transects were aligned parallel to the north-south section lines, which results in a grid

oriented to an artificial rather than a land form configuration and satisfies Cline's suggestion concerning the use of grid bases in soil sampling (Cline, 1944). The total number of gridding observations is 66 as opposed to 209 in the previous study.

At the [illegible] a trend [illegible]

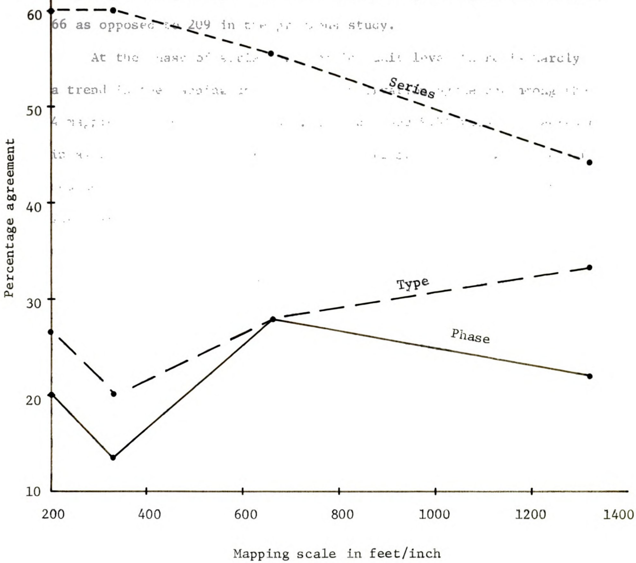


Fig. 34. Mapping unit-gridded observation agreement as a function of mapping scale.

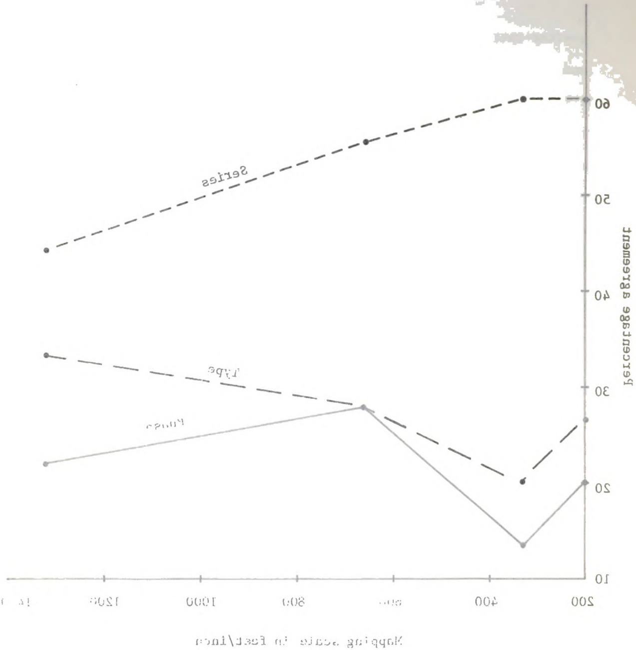


Fig. 34. Mapping unit-grid observation agreement as a function of mapping scale.

oriented to an artificial rather than a land form configuration and satisfies Cline's suggestion concerning the use of grid bases in soil sampling (Cline, 1944). The total number of gridding observations is 66 as opposed to 209 in the previous study.

At the phase of series or sampling unit level there is hardly a trend in the mapping unit-gridded observation agreement among the 4 mapping scales. There is a 2.2% actual and 9.9% relative decrease in agreement from the smallest to the largest scale map. The erratic scatter of the intermediate points suggests that differences at this level are due to variations among the quadrants rather than an effect of mapping scale.

At the type level one is tempted to visualize a decreasing trend in agreement percentage with increasing mapping scale. Possibly this is an effect induced by variations in surface texture over a short distance. This may be observed in the pattern of mapping and gridded observations in the southeastern quadrant of the composite map in Fig. 33. In particular, the large delineation in the center of the area, designated 4503/B1, contains 8 mapping observations and 8 gridded observations. Each group of observations covers the delineated area well. In addition, 6 of the mapping observations fall close enough to gridded observations to be considered pairs. Of these 6 pairs, in two the numbers are approximately 150 feet apart, and in the other 4, the distance of separation is less than 100 feet. Yet of these 6 pairs, 3 are composed of members of different series, and 2 others of members of different types.

In this study, the land form on which Miami sandy loam, 2-6% slopes (4503/B1), is delineated is a broad, gently-sloping, upland

ridge composed mainly of loamy, glacial-till material. Apparently a thin strata of sandy material covered the surface sometime in the past and has been removed by natural erosion until only remnants remain. These remnants vary in thickness from 10 to 30+ inches and are predominately sandy loam in texture. In places, a fragic horizon has formed near the sandy loam-loam contact. This hypothesis explains the occurrence of the soils described in all observations, both mapping and gridded, in this delineation, as can be seen in Table 14. One may envision the change from a Lapeer landscape to a Miami landscape with the gradual removal of the sandy capping by natural erosion. A condition such as this one is by no means unique; it is repeated many times throughout the Tri-County Soil Survey Area.

Only at the series level in Fig. 34 does agreement percentage increase with an increasing map scale. Although there seems to be a definite trend between the 1 inch = 1,360 foot and the 1 inch = 330 foot scale (15.6% actual and 26.0% relative increase), there is no difference between the 1 inch = 330 foot and 1 inch = 200 foot scale. Here again the land form and soil complexity of the 1 inch = 200 foot quadrant might have cancelled any normal increase attributable to mapping scale.

Mapping unit-gridded observation agreement in this study was superior to that of the previous section, but this probably is due to a switch to the southwestern quarter of Section 31, Meridian Township, in which the soils were basically simpler than those of the northwestern quarter. In particular, there were no large areas of low-lying, imperfectly and poorly drained soils of sandy texture. Soils like these, which tend to be stratified, seem to conjure up

Table 14. Soil-parent material relationships of the central delineation of the southeastern quadrant.

Miami sandy loam, 2 - 6% slopes (4503/B1)

Mapping unit	Soil	Parent material
4505/A1 & B1	Miami loam	Loamy till
4503/B1	Miami sandy loam	18" or less of sandy loam or loamy sand over loam
3493/B1	Owosso sandy loam	18" - 42" of sandy loam over loam
361/A1 & B1	Hodunk sandy loam	Sandy material in which a pedogenetic fragipan has formed
3643/B1	Lapeer sandy loam	Sandy loam material containing free carbonates within 42" of the surface

every conceivable concept of two-storied parent materials, overlays, truncations, and other weird combinations within the minds of all who work with them.

Conclusions which may be drawn from this section are:

1. Increasing the mapping scale does not necessarily ensure a more accurate soil map.
2. Of the mapping scales tried in this study, perhaps the 1 inch = 660 foot scale is the best compromise to show detail.
3. Remnants of old strata of sandy material over loam can yield a variety of soil series and types, within the same land form.
4. It is futile to attempt to map Miami sandy loam (4503) as a discrete mapping unit separate from Miami loam (4505), at least in the Tri-County Soil Survey Area.
5. The series Hodunk, which contains a fragipan layer, occurs most often as pedons or small poly-pedons rather than as mapping units in the Tri-County Soil Survey Area.

D. MORPHOLOGICAL DESCRIPTION OF TWO SOIL PROFILES BY SEVERAL OPERATORS

Nothing is more fundamental to soil classification than an accurate morphological description of the soil individual. Before a soil surveyor can formulate a concept of the range of characteristics of a soil series, he must be able to make an accurate morphological description of the soil as it is exposed in a soil profile. Because of the variation among operators' performances in the mapping unit analyses and standard quarter-section analyses, it seemed advisable to determine the agreement among several individuals describing the same soil profiles.

every conceivable concept of two-storied general education, overlaying,

truncations, [illegible] the minds of all

who work with

For this study two soil profiles were selected. One was a well drained, loamy soil with occasional lenses of sandy material, which is typical of the majority of the Miami profiles in the Tri-County Soil Survey Area. The other was a somewhat-poorly drained soil with a sandy upper profile and a loamy lower profile. This would have resembled the Metamora series except that the upper portion seemed to have been man-made. These profiles are shown in the photographs in Fig. 35.

Sketches of these profiles were made by Operator 10 and they are shown in Figs. 36 and 37. While these profiles are not as simple as some, they are no more difficult than many, and they served as excellent exercises to test the operators' skills in morphological evaluation.

Approximately 1 1/2 hours were required to describe each profile. The operators worked in pairs at each site, but did not communicate with each other. Operator 10 worked by himself at a later date. Operator 1 tried to describe the sites while acting as monitor and timekeeper. Operators 1, 3, 4, and 5 had participated in the standard quarter-section mapping analysis study. Operator 9 had mapped in the Tri-County soil survey for two seasons, and prior to that had served as a soil survey party leader in Iran for 7 years. Operator 10 had worked in soil survey, classification, and correlation for more than 20 years.

These profiles were described on the U.S.D.A., Soil Conservation Service soil description form SCS-232C, an example of which is included in the Appendix. No special instructions were given the operators except that they should spend no more than 1 1/2 hours per

For this study two soil profiles were selected. One was a well drained, loamy soil with occasional lenses of sandy material which is typical of the majority of the Miami profiles in the Tri County Soil Survey Area. The other was a somewhat-poorly drained soil with a sandy upper profile and a loamy lower profile. This would have resembled the Metamora series except that the upper portion seemed to have been man-made. These profiles are shown in the

The well drained soil profile.

The somewhat-poorly drained soil profile in the foreground is only about 50 feet from the well drained soil profile in the background.

Fig. 35. Photographs of the profiles described in this study.

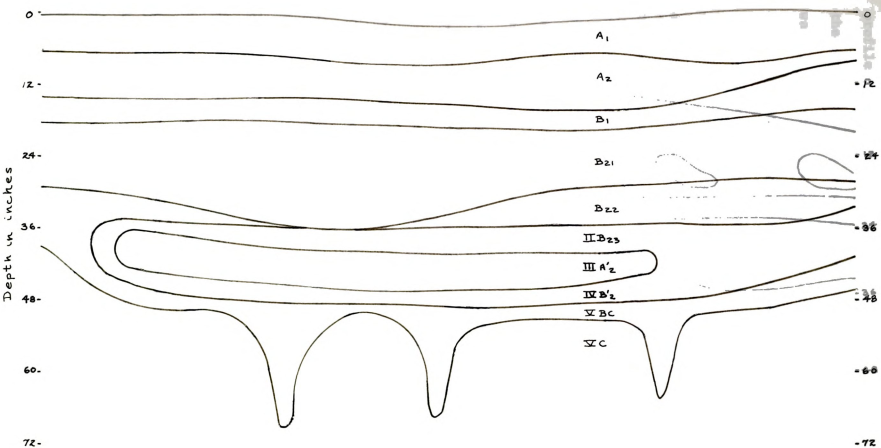


Fig. 36. A sketch of the well drained soil profile as observed and recorded by Operator No. 10. (Horizon notations are entered at description site)

Fig. 36. A sketch of the well drained soil profile as observed and recorded by Operator No. 10.
(Horizon notations are entered at description site)

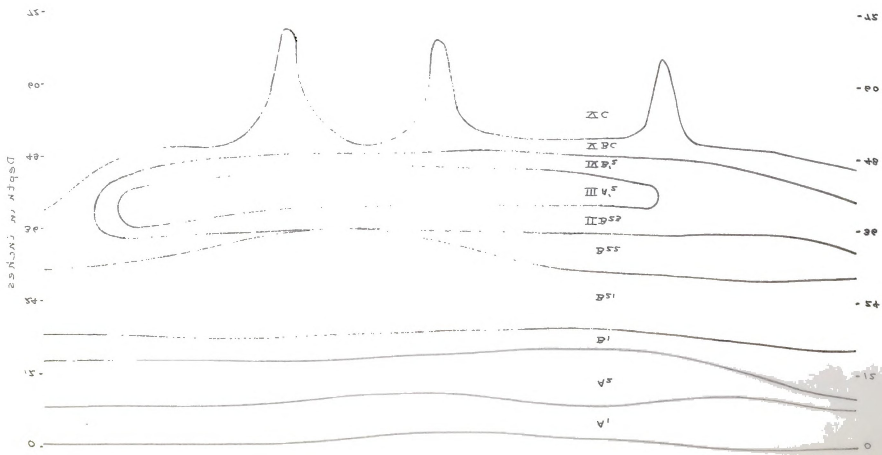


Fig. 37. A sketch of the somewhat-poorly drained soil profile as observed and recorded by Operator No. 10. (Horizon notations are entered at description site)

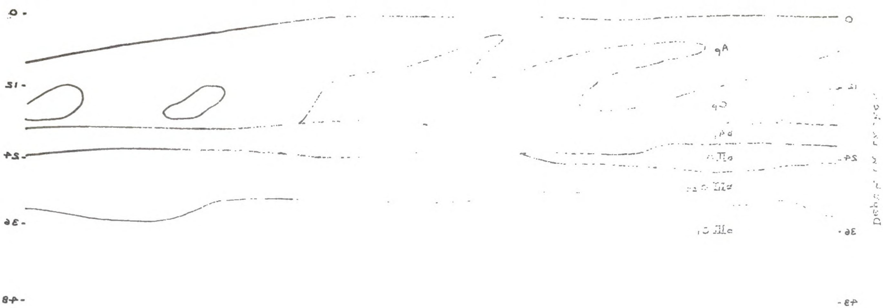


Fig. 37 A sketch of the somewhat-poorly drained soil profile as observed and recorded by Operator No. 10. (Horizon notations are entered at description site)

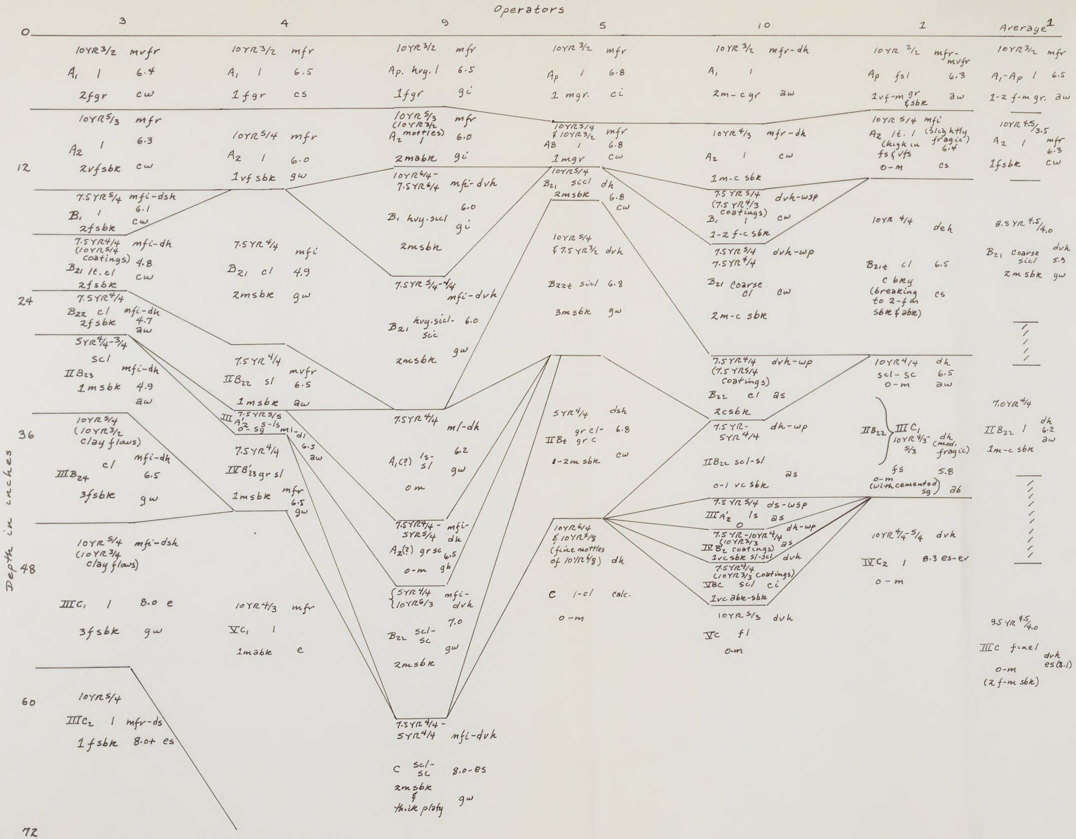
profile and should not communicate with each other while describing the profiles. They were allowed to use standard Munsell color books, water, hydrochloric acid, field pH kits, rulers, spades, picks, knives, and Abney levels while making the descriptions.

The descriptions of each operator have been compiled in Figs. 38 and 39. One of the most important parameters in soil morphological descriptions is the number of horizons and their nomenclature. In the well drained soil the number of horizons ranged from 6 to 10, with a mean of 7.7. The A horizon nomenclature among the operators was the most consistent with all recognizing two A's and agreeing on depths to within 2 inches. From the B_1 horizon down, things more or less fell apart and agreement is noted primarily by its absence. Three of the operators described B_1 horizons and three do not. All operators described B_{21} horizons, however. Most operators recognized a change in parent material at about 27 to 30 inches, although Operator 9 failed to use Roman numerals to indicate this change. Four of the operators observed the sandy lense at about 36 inches, although they handled it in different ways. Operator 1 included it as a lense in the II B_{22} horizon, although he designated it as III C_1 and called it a fine sand. Operator 4 divided it into three parts: an upper II B_{22} he called loamy sand, a III A'_2 only two inches thick he called sand to loamy sand, and a IV B'_{23} he called a gravelly, sandy loam. Operator 9 quite honestly designated it as A_1(?) and called the texture loamy sand to sandy loam. Immediately beneath it he described an A_2(?) gravelly, sandy clay. However, in his notes he described these horizons as discontinuous sand and gravel lenses. Operator 10 described a complicated sequence beginning

with a II B_{22} sandy clay loam to sandy loam, followed by a III A'_2 loamy sand, a IV B'_2 sandy loam to sandy clay loam, and a V BC sandy clay loam. After this, agreement among operators fell by the wayside and it was not regained until a depth of 5 feet was reached and everyone recognized a C horizon, although there was little agreement as to which C it was.

The author wanted to make as valid a comparison among the operators as possible, yet some parameters will not easily lend themselves to as simple a computation as an arithmetic mean. Thus, for horizon designation and boundary, structural form, and consistence, only a mode was determined. In the case of the other parameters - depth, color, texture, structural size and grade, and pH - a numerical value can be affixed and a mean determined. Therefore, it is possible to construct an average profile from the descriptions of the operators. This average profile is described in the last column of Figs. 38 and 39.

Determination of a mean textural value sometimes results in a textural class described nowhere else, as in the texture of the II B_{22} horizon of the average profile of the well drained soil. No other profile at a similar depth has that texture, yet it is a valid average among those textures described. The depths of 26" - 30" and 40" - 48" are undefined in this average profile. The first was caused by great fluctuation in lower boundaries of B_{21} horizons and upper boundaries of II B_{22} horizons. The latter was caused by lack of agreement in nomenclature and position of horizons used to describe the sand lense. Possibly the upper undefined zone



1 A combination of mode and mean.

2 Standard soil description abbreviations may be found in the Appendix.

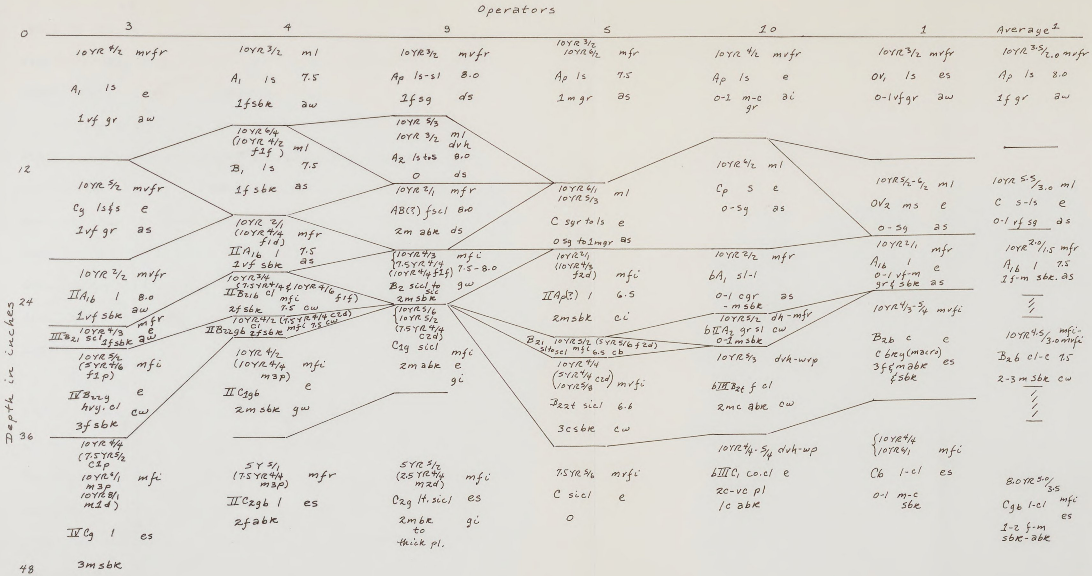
Fig. 38. A compilation of descriptions of the well-drained soil profile with horizons correlated wherever possible.[2]

Depth in inches	3	4	6	Operators
0	10YR 3/2 Mfr; A1 1 6.4; 2fgr cw	10YR 3/2 mfr; A1 1 6.5; 1fgr cs	10YR 3/2 mfr; Ap hvy.l 6.5; 1fgr gc	10YR 3/2; Ap 1; 1mgr.
	10YR 5/3 mfr; A2 1 6.3; 2vfsbk cw	10YR 5/4 mfr; A2 1 6.0; 1vfsbk gw	10YR 5/3 mfr (10YR 3/2 matrices); A2 1 6.0; 2msbk gc	10YR 3/2 & 10YR 3/2; A3 1; 1mgr
12	7.5YR 5/4 mfi-dsk; B1 1 6.1; 2fsbk cw		10YR 5/4-7.5YR 5/4 mfi-dvk; B1 hvy.scl 6.0; 2msbk gc	10YR 5/4; B21 scl; 2msbk
	7.5YR 4/4 mfi-dk (10YR 5/4 coatings); B21t cl 4.8; 2fsbk cw	7.5YR 4/4 mfi; B21 cl 4.9; 2msbk gw	7.5YR 5/4-4/4 mfi-dvk	10YR 5/4 & 7.5YR; B22t scl
24	7.5YR 4/4; B22 cl mfi-dk 4.7; 2fsbk aw		hvy.scl 6.0; gw	3msbk
	5YR 4/4-3/4 sc mfi-dk; II B23; 1msbk 4.9; aw	7.5YR [illegible]; B22 [illegible]; 1msbk aw	[illegible]	[illegible]
36	10YR 5/4 (10YR 3/2 clay flows); c mfi-dk; III B24 5.5; 3fsbk gw	[illegible]	[illegible]	[illegible]
48	10YR 5 [illegible] (10YR 3/2 clay flows); IIIC1 1 6.0; 3fsbk [illegible]	[illegible]	[illegible]	[illegible]
60	10YR 5/4; IIIC2 mfi-dk; 1fsbk 8.0 [illegible]		[illegible]	
72				

1 A composite [illegible]

2 Standard [illegible]

Fig. 38. A [illegible]



1 A combination of mode and mean

2 Standard soil description abbreviations may be found in the Appendix.

Fig. 39. A compilation of descriptions of the somewhat-poorly drained soil profile with horizons correlated wherever possible.[2]

could be divided between the B_{21} and the II B_{22}, but the lower zone would probably represent the sand lense, and no clear trend in nomenclature can be discerned for this.

In the analysis of the somewhat-poorly drained profile, less discrepancy among operator terminology was observed. All operators agreed that the upper two horizons were from a different parent material than the lower horizons. Although Operator 9 did not indicate this by horizon designation, he mentioned it in his description notes. Only Operator 1 did not give this material horizon designation, but used his own terminology to indicate there were two distinct layers of overburden covering the natural soil profile.

Three operators described the lower horizons as gleyed, or reduced due to water saturation over extended periods. The average of the somewhat-poorly drained descriptions names the upper two horizons Ap and C, concedes the next three to be buried, with the last one of this sequence, the Cgb, to be gleyed and buried. It considers all horizons as alkaline in reaction or containing free carbonates.

In this study the soil profiles were exposed in a borrow pit, readily available for intensive study and description. Still there was a great diversity in horizon separation and identification, and in the description of horizon morphology. In both profiles a plethora of horizon designations were used, although there was more variation in the well drained profile than the somewhat-poorly drained profile. Three operators identified the profiles. They agreed that the well-drained profile was Miami loam, but they hedged about the somewhat-poorly drained profile. One thought it was Conover, one

thought Blount loam or Conover loam, buried, and the third thought it was Conover loam with fill material overlying it.

From this portion of the study the following conclusions were apparent:

1. Although there is remarkable agreement among soil surveyors regarding soil morphology and horizon terminology in the simpler, easily recognized horizons, considerable discrepancy is introduced when irregularity in normal horizon sequence is encountered.
2. Although some variation exists among soil surveyors in evaluating soil morphology, apparently more exists when they are asked to put it all together and come up with a sequence of horizons, properly identified and described.

E. ESTIMATION OF SOIL TEXTURE BY SEVERAL OPERATORS

In the humid temperate regions soil drainage and texture are two of the most important soil morphological characteristics. Of all soil morphological characteristics, texture is supposedly one of the easiest to estimate. Certainly it is one of the easiest to determine in the laboratory. Yet from the variation among operators in evaluating texture in the previous section, there seemed to be a greater potential for difference among operators than was commonly conceded. To measure this difference was the purpose of this study.

Samples from 20 horizons of 6 Michigan soil series were selected for this study. Of the 12 possible classes on the textural triangle, 7 were represented by these samples. Although the silty side of the triangle was slighted, some of the samples contained a sizeable silt component and were judged too silty. There were estimates

representing every textural class on the triangle except silt.

Analyses of the samples are given in Table 15. Samples fairly well covered class extremes except for sandy clay loam which lacked a coarse member, and clay which lacked a representative from its finer range. These samples represented horizons varying from A_2 to C, which permitted a wide range of colors and levels of humified organic material. In each class an attempt was made to select samples with as much variation in texture and general appearance as possible to avoid triggering association responses to some visual clue. Although not intentionally selected for that reason, some samples fell close to class boundaries (Fig. 40).

The plot of samples on the textural triangle in Fig. 40 can best illustrate possible responses among operators participating in this exercise. Visually following the triangle from the lower left corner along the observation scatter one notices the proximity to textural class boundaries of sample nos. 43, 23, 55, 59, 27, and 77. Normally an operator might estimate sample no. 43 as either sand or loamy sand. If his answer were sand, he deserved full credit; but if he answered loamy sand, he still deserved partial credit.

To evaluate the answers, a ranking scale of 5 to 0 was used. This was based on the distance a sample plot was located from a class boundary on a standard textural triangle (Soil Survey Staff, 1951, p. 209). Using sample no. 55 as an example - an answer of sandy loam was given full credit of 5%; an answer of loam, which is 2 spaces from the observation plot, was given 3%; an answer of sandy clay loam, 4 spaces away, was given 1%. Thus:

Table 15. Particle size analyses of samples used in textural evaluation study.

Sample number	Soil series	Horizon	Sand %	Silt %	Clay %	Textural class
5	Oshtemo	B_1	79.9	15.7	4.5	Loamy sand
7	Oshtemo	B_{21}	83.6	11.5	5.1	Loamy sand
15	Hillsdale	A_2	61.9	30.8	7.2	Sandy loam
17	Hillsdale	B_1	64.4	25.0	10.7	Sandy loam
21	Hillsdale	B_{22}	67.6	15.7	16.6	Sandy loam
23	Hillsdale	B_3	78.2	10.7	10.6	Sandy loam
25	Hillsdale	C	70.8	19.6	9.5	Sandy loam
27	St. Clair	A_1	30.5	43.7	25.9	Loam
29	St. Clair	A_2	26.0	41.0	33.2	Clay loam
33	St. Clair	B_{22}	16.9	37.9	45.5	Clay
43	Granby	A_1	89.5	6.3	4.2	Sand
47	Granby	Bir	94.5	2.8	2.7	Sand
53	Miami	B_{11}	57.3	34.1	8.6	Sandy loam
55	Miami	B_{12}	53.8	29.7	16.5	Sandy loam
59	Miami	B_{22}	50.8	26.8	22.4	Sandy clay loam
63	Miami	C_1	38.1	38.7	23.2	Loam
65	Miami	C_2	47.1	33.1	19.8	Loam
67	Napanee	Ap	29.0	35.1	36.2	Clay loam
71	Napanee	B_{21t}	19.9	31.6	48.4	Clay
77	Napanee	C_1	23.1	34.7	42.3	Clay

Spaces of answer from sample plot	Percentage
0	5
1	4
2	3
3	2
4	1
5+	0

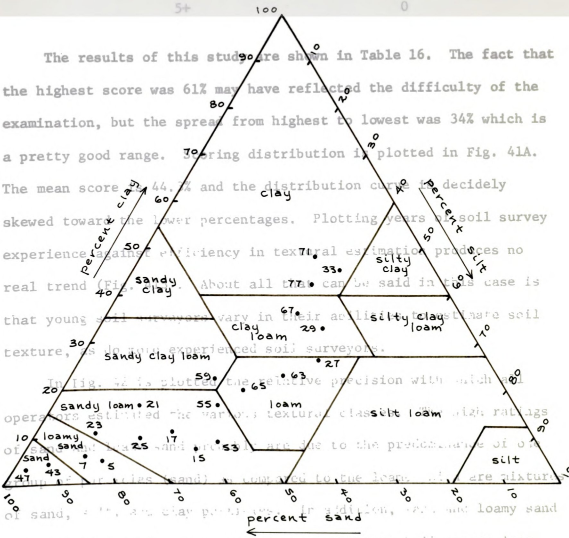


Fig. 40. A particle size plot of samples used in the textural evaluation study.

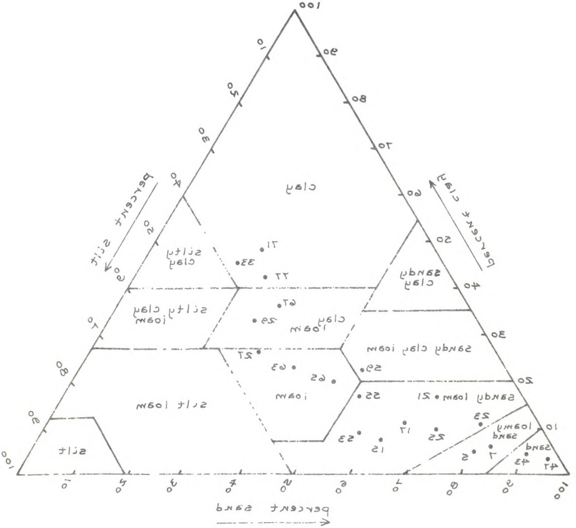


Fig. 40. A particle size plot of samples used in the textural evaluation study.

Spaces of answer from sample plot	Percentage
0	5
1	4
2	3
3	2
4	1
5+	0

The results of this study are shown in Table 16. The fact that the highest score was 61% may have reflected the difficulty of the examination, but the spread from highest to lowest was 34% which is a pretty good range. Scoring distribution is plotted in Fig. 41A. The mean score is 44.3% and the distribution curve is decidely skewed toward the lower percentages. Plotting years of soil survey experience against efficiency in textural estimation produces no real trend (Fig. 41B). About all that can be said in this case is that young soil surveyors vary in their abilities to estimate soil texture, as do more experienced soil surveyors.

In Fig. 42 is plotted the relative precision with which all operators estimated the various textural classes. The high ratings of sand and loamy sand probably are due to the predominance of one group of particles (sand) as compared to the loams which are mixtures of sand, silt, and clay particles. In addition, sand and loamy sand are encountered with frequency in the Tri-County Soil Survey Area. Sandy loam and loam are the most frequently encountered, however, and they were handled well by the operators, although admixing of other particle sizes began to complicate the process of estimation. Sandy clay loam was poorly represented by only one sample, and it was a borderline case. Therefore, its rating precision is probably lower than it should be. As for clay loam and clay, only minor amounts of

Table 16. Textural examination tally sheet.

Sample no.	Textural class	Operators 2	3	4	5	9	13	14	15	Σ Sample	Σ Class	$\bar{x}$ Class	Average % score
		Score in percent											
43	s	3	5	5	3	0	5	3	3	27			
47	s	0	5	5	5	0	5	5	0	25			
Σ class by operator		3	10	10	8	0	10	8	3		52	26.0	65.0
5	ls	5	0	0	5	5	5	0	0	20			
7	ls	5	5	2	5	5	5	2	2	31			
Σ class by operator		10	5	2	10	10	10	2	2		51	25.5	63.8
15	sl	0	5	5	0	0	5	0	5	20			
17	sl	5	0	5	0	5	5	0	0	20			
21	sl	1	5	5	0	1	1	1	1	15			
23	sl	5	4	4	4	5	5	4	5	36			
25	sl	5	5	0	5	5	5	0	5	30			
53	sl	0	5	5	0	0	0	5	5	20			
55	sl	0	1	5	3	1	0	1	3	14			
Σ class by operator		16	25	29	12	17	21	11	24		155	22.1	55.3

Table 16. (Cont.)

Sample no.	Textural class	Operators 2	3	4	5	9	13	14	15	Σ Sample	Σ Class	$\bar{x}$ Class	Average % score
		Score in percent											
27	1	0	0	5	5	0	0	0	4	14			
63	1	1	5	5	5	1	0	1	1	19			
65	1	0	5	0	5	0	5	0	5	20			
Σ class by operator		1	10	10	15	1	5	1	10		53	17.7	44.3
59	scl	0	5	3	0	0	0	0	0	8			
Σ class by operator		0	5	3	0	0	0	0	0		8	8.0	20.0
29	cl	0	0	0	0	0	0	0	0	0			
67	cl	5	0	5	0	0	1	5	0	16			
Σ class by operator		5	0	5	0	0	1	5	0		16	8.0	20.0
33	c	2	0	0	0	5	5	0	0	12			
71	c	0	0	0	0	5	0	0	0	5			
77	c	0	0	2	0	0	0	0	0	2			
Σ class by operator		2	0	2	0	10	5	0	0		19	6.3	15.8
Total by operator		37	55	61	45	38	52	27	39	Σ 354 $\bar{x}$ 44.25		17.7	44.3

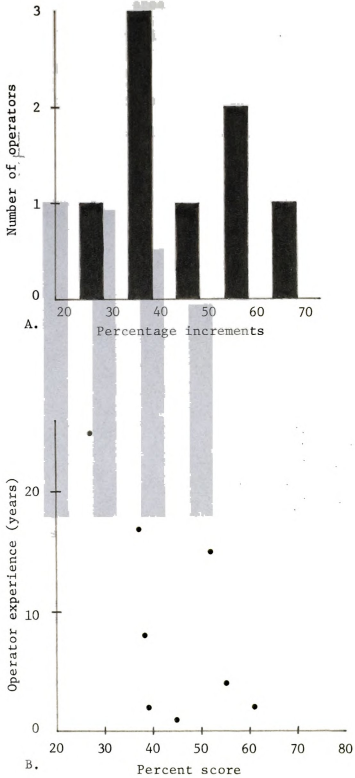
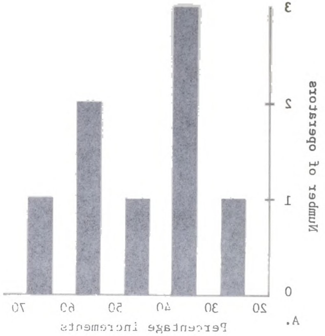
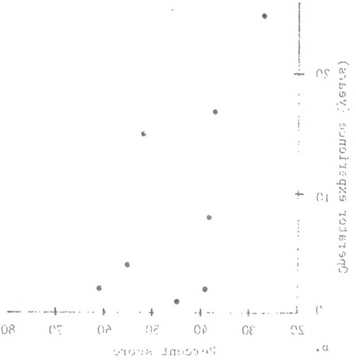


Fig. 41. Grade distribution and influence of experience on estimation of texture.



A.



B.

Fig. 41. Grade distribution and influence of experience on estimation of texture.

clay are found in the survey area, and therefore, soil surveyors become conservative and are inclined to designate as clay loams textures that feel like clay.

When texture of the surface soil is incorrectly estimated by a soil surveyor, it usually results in improper classification at phase of series

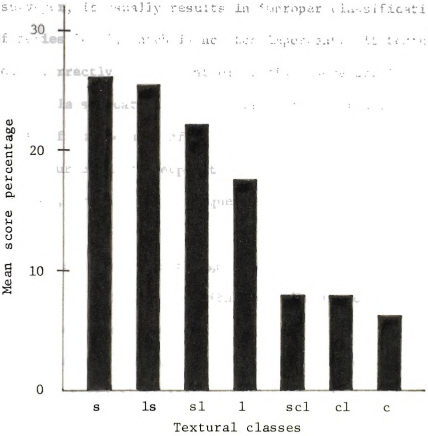
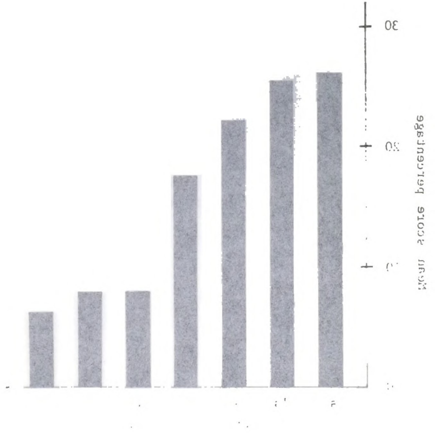


Fig. 42. Relative precision with which textural classes were estimated by all operators.


30
20
Mean score percentage

clay are found in the survey area, and therefore, soil surveyors become conservative and are inclined to designate as clay loams textures that feel like clay.

When texture of the surface soil is incorrectly estimated by a soil surveyor, it usually results in improper classification at phase of series level, which is not too important. If texture is estimated incorrectly in the control section, however, it can result in erroneous classification at the series or even family level.

In view of the results of this study, it would seem advisable for all soil surveyors to keep sets of analyzed textural samples in their vehicles, available for frequent reference and periodic practice.

From this study certain things seem apparent:

1. Estimation of soil texture with precision is not easy, even for experienced soil surveyors.
2. Coarser textural classes are estimated with greater precision than finer textural classes by soil surveyors in the Tri-County soil survey.
3. No relationship seems to exist between precision in estimating texture and length of soil survey experience among men with one year or more of experience.
4. It is futile to try to separate mapping units on the basis of a textural variation of only a few percent (10% or less) even if the two units straddle textural class boundaries.

F. THE CONCEPTUAL RANGE OF CONOVER LOAM AS ENVISIONED BY THREE OPERATORS

In Section V E it was established that competent soil surveyors with a year or more of experience could evaluate soil texture with a fair degree of accuracy. Yet when competent operators attempted to describe two soil profiles in Section V D there was considerable discrepancy in their results. Because of a similar lack of agreement in the treatment of the standard quarter-section examined in Section V B, the lack of precision at all scales considered in the mapping scale study in Section V C, and the lack of mapping unit precision in the mapping unit analyses in Section V A, apparently some of the trouble lay in the soil surveyors' concepts of the taxonomic unit at the phase of series level.

Operators 3 and 5 agreed to assist Operator 1 in locating and marking three Conover loam profiles - a modal profile (central concept), a "high-side" profile (marginal to Celina loam), and a "low-side" profile (marginal to Brookston loam). Thus there would be three profiles to span the somewhat-poorly drained Conover loam, ranging just up to the edge of the moderately-well drained Celina loam and just down to the edge of poorly drained Brookston loam. If there were general agreement among the operators as to the concept of Conover loam, the descriptions should be similar. To eliminate discrepancies in observation, Operators 3 and 5 were not asked to write descriptions, just to locate and identify the points on the landscape where these conditions occurred. They used yellow plastic flags for this purpose, writing the identification on them and inserting their wire staffs into the ground at the chosen spots.

Because of intensely cold weather Operator 1 removed cores

of each profile with a bucket auger and essentially rebuilt the profiles in 42-inch sections of gutter. These tin troughs were carried to the laboratory where they were described by Operator 1, working under fluorescent light.

By this method of one person writing all the descriptions, elimination of subjective bias among operators was sought. At least all bias of soil description would be like-bias, that bias of Operator 1.

A comparison of the modal Conover loam profiles is given in Fig. 43. The descriptions of Operators 1, 3, and 5 are outlined along with the official series description (National Cooperative Soil Survey, 1967). Abbreviations used are from the Soil Survey Manual (Soil Survey Staff, 1951, pp. 139-141) and the Supplement to the Soil Survey Manual (Soil Survey Staff, 1962, pp. 173-188) and are summarized in the Appendix. A legend is placed at the bottom of the figure as a location guide to the morphological features described in each horizon. Since these are descriptions of the "modal Conover loam," they should be fairly close to the description of the "typifying pedon" of the Conover series with modifications due to local environment. As a reference, the official description of the Conover series is included in the Appendix.

In comparing these profile descriptions, the author was surprised to note each profile had a different horizon sequence. The profile selected by Operator 3 lacked an A_2, and the solum lacked the 24-inch minimal thickness allowed in the range of characteristics of the official description. The profile selected by Operator 5 had a B_1 horizon, while the profile selected by

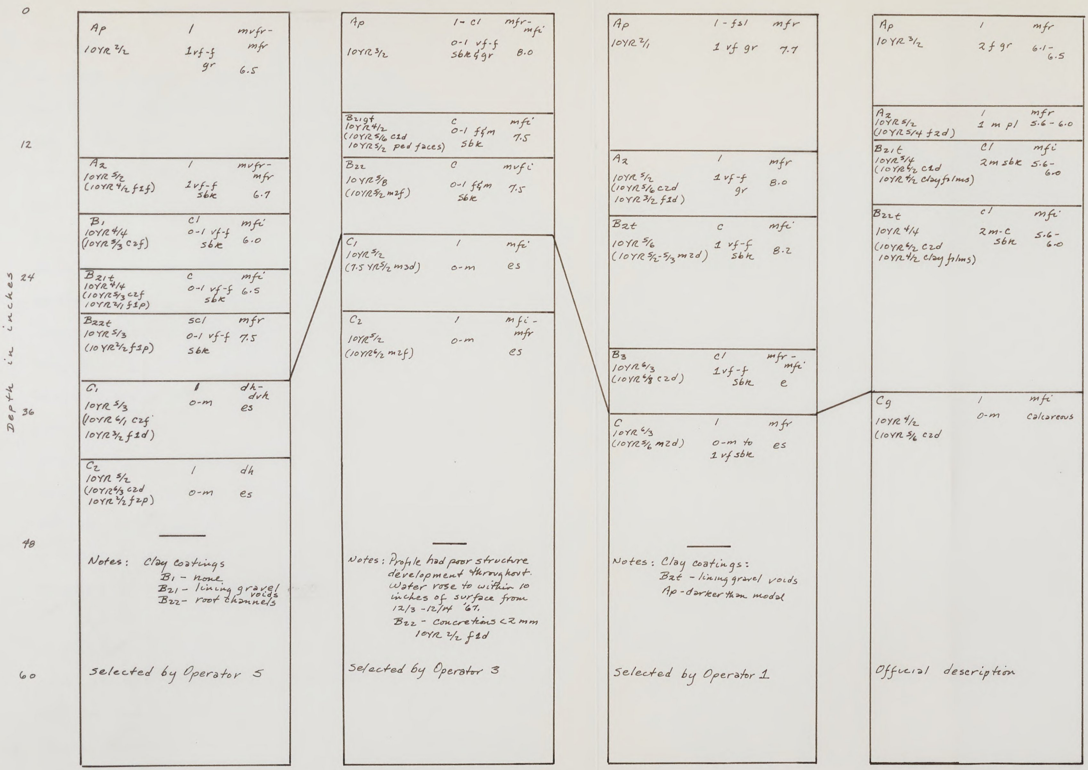


Fig. 43. Descriptions of Conover loam (modal) from sites selected by three operators.

Operator 1 did not have a subdivided B_{2t}. Part of the B horizon in each description was evaluated texturally as clay, which may have been a result of a tendency on the part of Operator 1 to overestimate clay content of the B horizons of the loamy Michigan soils. If a reduction of 5% in clay content is made, then all B horizons would fall within the concept of the typifying pedon of the official series description, except the B_{22t} of the profile described by Operator 5, which does not lie within the allowable range of textures for the B_t. Apparently the authors of the official description overlooked a component of considerable extent in setting the range limits of this series when they failed to allow for the inclusion of lenses of sandier material within the B_{2t} horizon. This is not to say the Locke series should be included within the Conover range, but that Conover should include within its concept the "sandy loam sandwich" condition where a lense of sandy material is found with loam above and loam below. Certainly it would be highly impractical to attempt to set up a separate series for such a condition, and virtually, impossible to separate it on a soil map.

In defining the upper extent of the Conover range, variation in profiles again was quite evident (Fig. 44). In his zeal to select the upper edge of the Conover range, Operator 1 slipped over into the lower edge of the Celina range with a profile having no chroma 2 mottling until a depth of 20 inches. This profile is further complicated by the sand layer from a depth of 10 to 20 inches, which encompasses the A_2 and B_1 horizons. Beneath this is a horizon weak in structural development and which effervesced strongly, but which was still called B_{2t} by Operator 1. If the presence of free

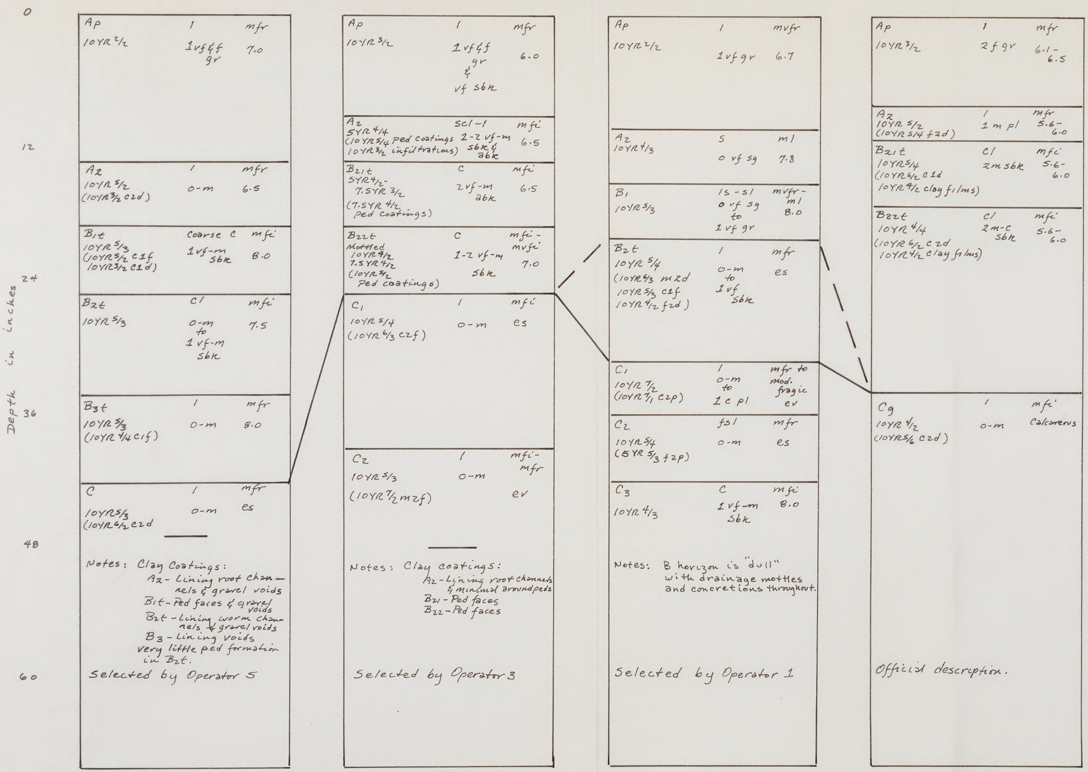


Fig. 44. Description of Conover loam (high side - marginal to Celina) from sites selected by three operators.

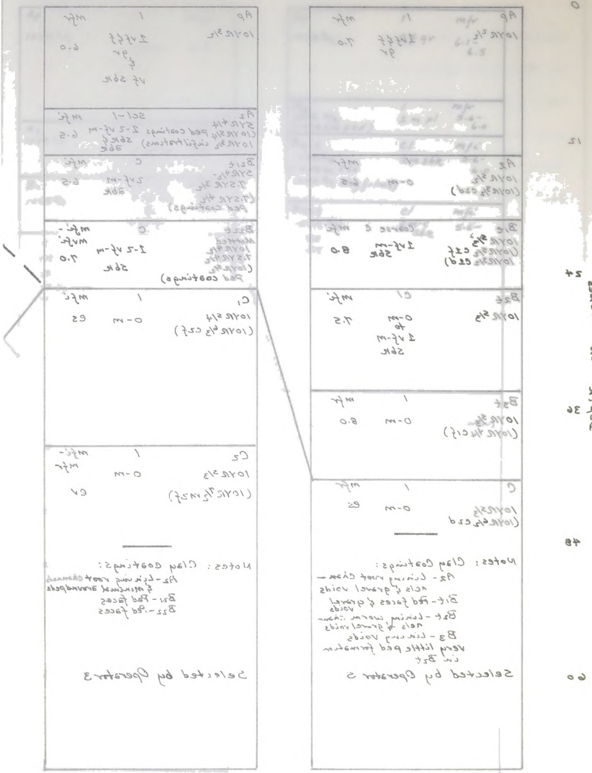


Fig. 44. Description of Corwin loam: high side - marginal to (Cerina) from

carbonates is an absolute criterion for a C horizon, then this fails to meet B horizon requirements, and solum depth terminates at 20 inches, which is the minimum limit for Celina (see Appendix).

Operator 3 selected a profile having a B_{21t} and B_{22t} matrix of chroma 2, which is outside the range of Conover, but within the limits of Brookston. Upon completing this description, Operator 1 noted that he would have called this profile Celina, influenced by its 5 3/4% slope gradient, evidence of low-chroma infiltrations, and the shallow depth to the C horizon - the second and third factors seeming to produce lower-than-normal chromas in some loam-till soils.

The profile selected by Operator 5 has the thickest solum of all, with chroma 2 mottling from 13 to 25 inches, but with no more occurring until the C was reached at 42 inches. This poses another problem: how does one ignore a 17-inch unmottled layer in a soil profile in which mottling should increase with depth? The matrix color of the B_{2t} horizon is within the color range of the Celina B_{2t}. Only weak structural development is observed in the B_2 horizon, and the B_3 is structureless. Still the B_3 shows evidence of translocated clay.

At its more poorly drained extreme the Conover series approaches the Brookston series (see Appendix). Brookston, like Celina, is described from a typifying pedon formed in loess overlying loam till (National Cooperative Soil Survey, 1967), which further complicates comparisons in the loess-free Tri-County Survey Area. Once again profiles chosen by the three operators differed markedly.

As can be observed in Fig. 45, Operator 5 picked a profile with a 20-inch solum. Texture of the B_{21t} and B_{22t} horizons was probably [illegible] to an absolute criterion [illegible], then this would

to meet a further requirement [illegible]

tasks, which [illegible]

[illegible]

[illegible]

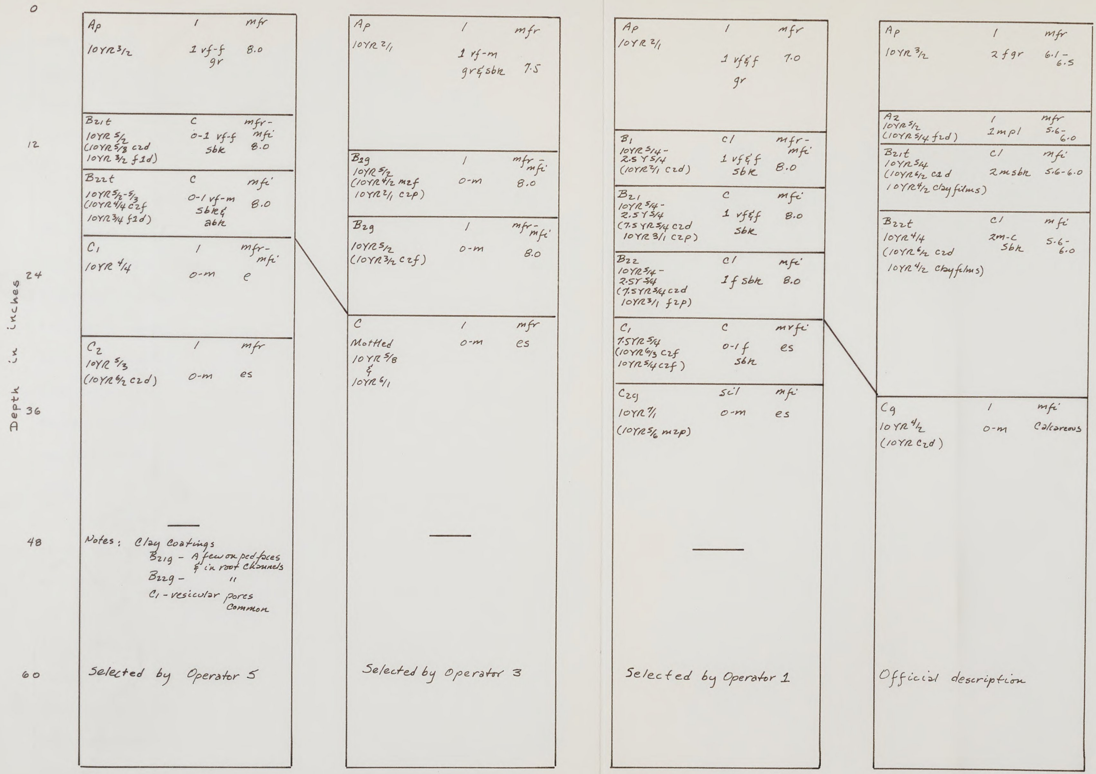


Fig. 45. Descriptions of Conover loam (low side - marginal to Brookston) from sites selected by three operators.

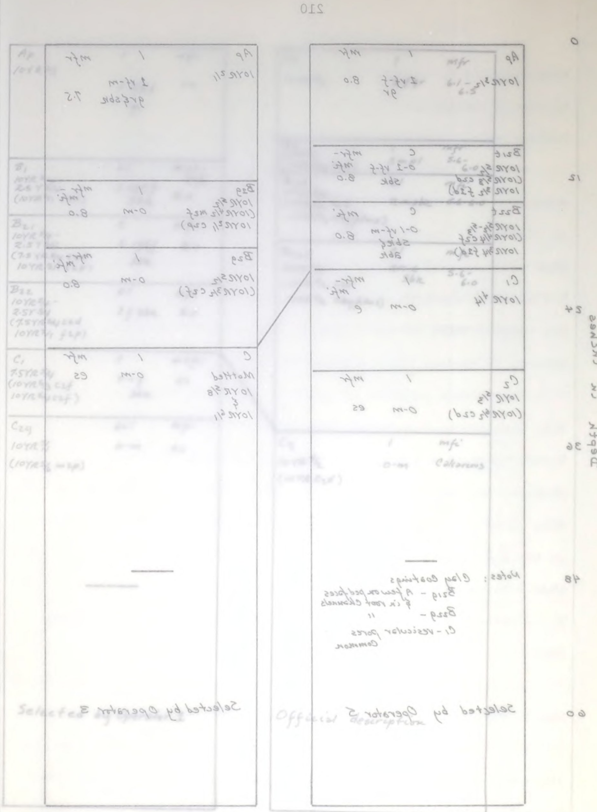


Fig. 45. Descriptions of Conover loam (low side - marginal to Brookston.

near the clay loam-clay boundary even though it was described as clay. Matrix chroma of B_{21g} is too dark for Conover, as is B_{22g}, although it is approaching an acceptable chroma. Although matrix colors of the solum indicate Brookston, the C_1 seems to have too high a matrix chroma and is more like a Celina C.

In a like manner Operator 3 selected a low-chroma profile. Throughout the depth of the solum no color - matrix or mottle is higher in chroma than 2. This would fit much better into the Brookston concept than the Conover from a standpoint of color. The texture is uniformly a loam from the Ap to the parent material. It is a weak profile with little structural development or evidence of clay translocation noted in the solum, yet there seemed to be enough evidence in the general appearance of the profile to designate a B_{1g} and B_{2g} horizon, giving the solum a depth of 27 inches.

A profile more nearly resembling that allowable in Conover was chosen by Operator 1. Matrix colors of B horizons are chroma 4, while mottles of chroma 1 are common throughout most of the solum. The B_{21} and C_1 are called clay, but probably are marginal to clay loam. The C_1 represents 6 inches of parent material apparently free from low-chroma mottles and having some weak structural development. However, Operator 1 noted when describing this profile that, although marginal between Conover and Brookston, he would call it Brookston. Apparently he was influenced by the number of low-chroma mottles high in the solum and felt this indicated a much higher zone of saturation for long periods of time than was allowable in Conover.

The author recognizes the inherent weaknesses in this type of description and would have much preferred pit descriptions. Time, however, was the limiting factor in this study, and spade and auger descriptions were the only means available to gather the information. Since all profiles were described in a like manner, there should be some validity in the differences noted among individuals. If this validity exists, then there were disturbing discrepancies in range limit concepts among operators. In addition, significant gaps in the official series description were observed.

In Table 17A the range of matrix colors for the entire B horizon of each profile described is given for each operator. Since the presence of chroma 2 or less in either matrix or mottle colors is considered diagnostic of imperfect internal drainage, the presence of these chromas and their depth in the profile are of primary importance in establishing the boundaries between the Conover series and adjacent members of the Miami toposequence.

Operator 3 selected profiles having chroma 2 matrix colors at 13, 9, and 12 inches for high, modal, and low Conover profiles. All of these are excluded from the matrix chroma range of the official description. His mottling chromas are within the official range, except for the low profile which is much lower in value than the official low range.

A real problem arises when one attempts to match Operator 3's modal profile to the official description (Fig. 43). Although the B_{21tg} has a matrix color of 10YR 4/2, the B_{22} (13 - 20 inches) has a matrix color of 10YR 5/8. Instances such as this which occur repeatedly emphasize the fact that even modern series descriptions are

Table 17. A comparison of B horizon matrix and mottle colors spanning the range of the Conover series as envisioned by three operators.

A)

Conover profiles	B horizon matrix color: Operator 5	Operator 3	Operator 1	Official description
"High side"	10YR 5/3[1] (19)[3]	5YR 4/2 - 10YR 4/2 (13)	10YR 5/4 (20)	10YR 6/3 - 4[2]
Modal	10YR 5/3 - 4/4 (27)	10YR 4/2 - 5/8 (9)	10YR 6/3 - 5/6 (30)	10YR 4/4 - 5/4[4] (11)
"Low side"	10YR 5/2 - 5/3 (9)	10YR 5/2 (12)	10YR 5/4 - 2.5Y 4/4 (10)	10YR 4/3 - 4[2]

Table 17. (Cont.)

B) B horizon mottle color

Conover profiles	Operator 5	Operator 3	Operator 1	Official description
"High side"	10YR 3/2 - 5/2 (19) (19)	7.5YR 4/2 (13)	10YR 4/2 - 6/3 (20)	10YR 6/2 (11)
	10YR 4/4	10YR 5/2 (19)		
Modal	10YR 2/1 - 5/3 (23)	10YR 5/2 - 5/6 (9)	10YR 5/2 - 6/8 (18)	10YR 4/2 - 6/2 (11)
"Low side"	10YR 3/2 - 5/8 (9)	10YR 2/1 - 4/2 (12)	7.5YR 5/4	10YR 5/1
			10YR 2/1 (10)	

[1]Colors listed represent range for all B subhorizons.

[2]Listed as range for entire series.

[3]Numbers in parentheses represent depth (inches) first encountered.

[4]Color of typifying pedon.

not mutually exclusive. To quote from the Brookston series description:

> It [the A] is black (10YR 2/1) or very dark grayish brown (10YR 3/2)...The B_2 horizon ranges from 10YR through 5Y hue or is neutral (N), has value of 4 through 6, and chroma of 1 or 2. It contains few to common, faint to distinct mottles of 10YR or 7.5YR hue, value of 4 through 6, and chroma of 1 through 8 (National Cooperative Soil Survey, 1967).

Assuming the modal profile of Operator 3 has a loam A and a clay loam B, then a strict application of official matrix color range would exclude it from either Conover or Brookston.

The preceding discussion has centered on the comparison of "high," modal, and "low" Conover loam profiles selected by three individuals from a Conover loam delineation of approximately 5 acres in areal extent. Comparisons have been made largely on the basis of matrix and mottle color, particularly chroma, since this is the parameter of prime importance in distinguishing among the soils of the Miami toposequence. No attempt has been made to compare the permutations possible with the parameters recorded in these descriptions, although this is the avowed purpose of soil correlation. Such a study would be far too lengthy and involved to fit into the space available here.

Conclusions which may be drawn from this section are:

1. The conceptual range of a soil series varies among operators, and to a great extent among some.
2. There is great variability in color and texture among pedons over a small area of supposedly similar soils.
3. While soil series descriptions have improved greatly in recent years, careful and thorough study should be devoted to the section on range in characteristics to make it include many more

of the variations found in the soil landscape.

G. COMPARISON OF THE PHYSICAL PROPERTIES OF FIVE IMPORTANT TRI-COUNTY SOIL SERIES

For many years soils engineers have recognized the problems involved in sampling and testing soils:

> On account of the time required for making complete soil tests...these tests must of necessity be confined to a very restricted number of soil samples. On the other hand, in consideration of the important variations in physical properties of materials of the same soil deposit, we are interested in complete tests of as many samples as possible, in order to obtain average values which will be representative of the entire deposit.
>
> As a matter of fact, experience seems to show that nothing like a homogeneous soil deposit exists. This is true for both residual and transported soils (Terzaghi, 1928, p. 151).

An eminent research organization elaborates on this theme:

> The science of soil mechanics is a complex one, due to the very nature of the materials involved which vary not only geographically but locally as well.
>
> ....
>
> The very fact of having test methods for the study of soil properties may suggest to the unwary that soils are similar to other materials of construction, and therefore always susceptible to routine testing in the laboratory. That this is not the case, all who have gained experience in the use of soil mechanics know well. The necessity for the vital use of judgment in all phases of soil testing should never be forgotten.
>
> ....
>
> Soil engineers should realize that they are dealing with an inherently variable, complex, and in many respects an unusual kind of engineering material in their work with soils ....The character and responses of soils are inherently variable and complex products of geological processes and the natural environment is a fundamental factor (American Society for Testing and Materials, 1964, pp. iii - 5).

The highway engineering soil survey, which is essentially based on a transect following the proposed highway route, has been evaluated in the following manner:

> The soil survey is as important to the proper design of the

> pavement structure as the classification and strength tests. If the information recorded and the samples submitted to the laboratory are not representative, the results of the tests, no matter how precise, will be misleading and meaningless. The soil survey, therefore, must be made with accuracy (The Asphalt Institute, 1961, p. 16).

These admonitions could well apply to basic soil surveys. These basic surveys, called "Agricultural Soil Maps" by the previous source, evoke the following comment:

> The scale to which these maps normally are drawn does not permit the showing of certain details which are frequently important to the engineer. For example, if, within a given soil area, a small area of other soils (series or type) is present, and these soils are similar agriculturally, they are not identified generally unless they represent more than 10 or 15 percent of the soil area in which they are included. Generally, soils from the same horizon and the same series will exhibit similar engineering properties within acceptable limits. There are, of course, exceptions to this rule. The soils engineer must obtain sufficient samples and perform the necessary tests to minimize the possibility of this exception going unnoticed (The Asphalt Institute, 1961, pp. 37-38).

In Michigan, a variety of soil conditions important to highway construction have been summarized in the Field Manual of Soil Engineering:

> The drift deposited during its [the Wisconsin Ice Sheet] recession formed features varying from flat, level lake beds to the very rough terrain of moraines. The material of these formations varies from clay to gravel. The granular textures may be segregated or mixed heterogeneously with boulder clays. One hundred and forty-one different soils formed by these simple or complex arrangements are mapped and used by the Michigan State Highway Department.
>
> Because of the number and complexity of Michigan soils any method used in making soil surveys requires a great deal of study and research to adapt it to road and bridge construction (Michigan State Highway Department, 1960, p. 10).

The value of diverse approaches in soil testing has been debated in some detail:

> ...More and more emphasis has been placed on refinements in

> sampling and testing and on those very few problems that can be solved with accuracy. Yet, accurate solutions can be obtained only if the soil strata are practically homogeneous and continuous in horizontal directions. Futhermore, since the investigations leading to accurate solutions involve highly specialized methods of sampling and testing, they are justified only in exceptional cases. On the overwhelming majority of jobs no more than an approximate forecast is needed, and if such a forecast cannot be made by simple means it cannot be made at all....
>
> To achieve this goal [satisfactory results in earthwork and foundation engineering at a reasonable cost] the engineer must take advantage of all the methods and resources at his disposal - experience, theory, and soil testing included (Terzaghi and Peck, 1948, pp. v-vi).

The status of soil testing as related to the classification of soils under the new system by the National Cooperative Soil Survey has been estimated:

> Only rarely do we have laboratory data from more than 10 individuals in a taxon of the lowest category, the soil series, or more than 20 in a taxon of the next highest category, the family (Smith, 1965, p. 19).

In order to realize maximum value from the soil survey and map, judicious sampling and testing of pedons representing the important soil types are required. Once the characteristics of these soil types are determined, their behavior may be predicted whenever they are encountered on the soil map <u>provided the mapping is accurate and the predictions are applied to the taxonomic unit giving the mapping unit its name, and not the inclusions</u>.

In order to more accurately evaluate their differences in suitability for non-agricultural uses, 5 of the commonly encountered soil types of the Tri-County Soil Survey Area were described, sampled, and analyzed for important physical characteristics. These soils were Miami loam, Conover loam, Blount loam, Boyer sandy loam,

and Chelsea loamy sand[1] (descriptions of these profiles are included in the Appendix). While these soils represent only a fraction of the soils identified and mapped in the Tri-County Soil Survey Area (see Tri-County mapping legend, Appendix), they serve as benchmarks from which information applicable to other series may be extrapolated.

These soils sampled were considered by the author as profiles representative of the series as encountered in the survey area. Photographs of these soil profiles are shown in Fig. 46. They represent a range of textures from nearly the coarsest to nearly the finest found in the survey area. The parent materials from which these series formed are similar to those which contributed to the formation of most series of the area.

Samples of these soils were analyzed to determine texture, bulk density, porosity, moisture desorption characteristics, and swelling potential. Complete analyses are included in the Appendix.

One of the most fundamental soil physical measurements is the determination of particle size distribution. This analysis is important to the understanding of release and fixation of plant nutrients, soil-water relationships, and suitability of a soil for engineering purposes. When plotted as a function of profile depth, this distribution is a valuable aid in making a variety of interpretations, such as: selection of adapted plant species, suitability for septic tank drainfield systems, and potential for highway fill material. In this study, particle size distribution was determined by the method of Kilmer and Alexander

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[1]A discussion of the problems involved in the series placement of this pedon is given in the Appendix.

A. Blount loam

B. Conover loam

Fig. 46. Photographs of soils sampled for physical analysis.

C. Miami loam

Fig. 46. (Cont.)

D. Miami-Conover landscape

E. Boyer sandy loam

F. Boyer landscape

Fig. 46. (Cont.)

G. Chelsea loamy sand

H. Chelsea landscape

Fig. 46. (Cont.)

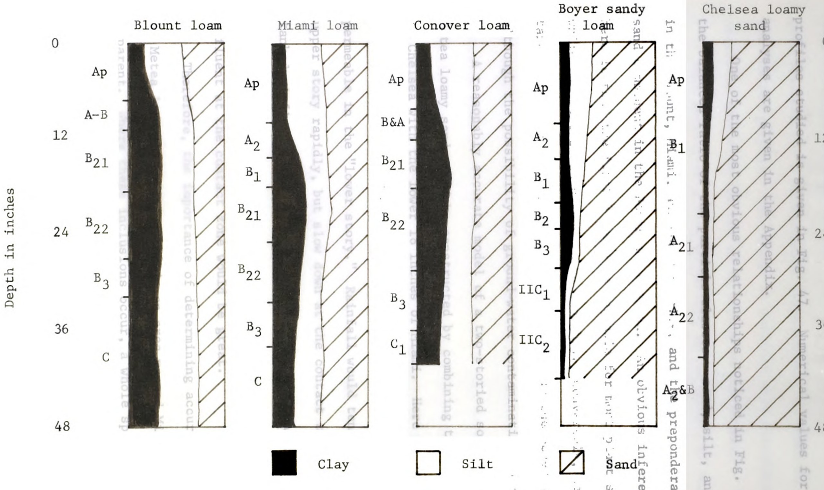

Fig. 47. A schematic representation of particle size distribution in the soil profiles studied.

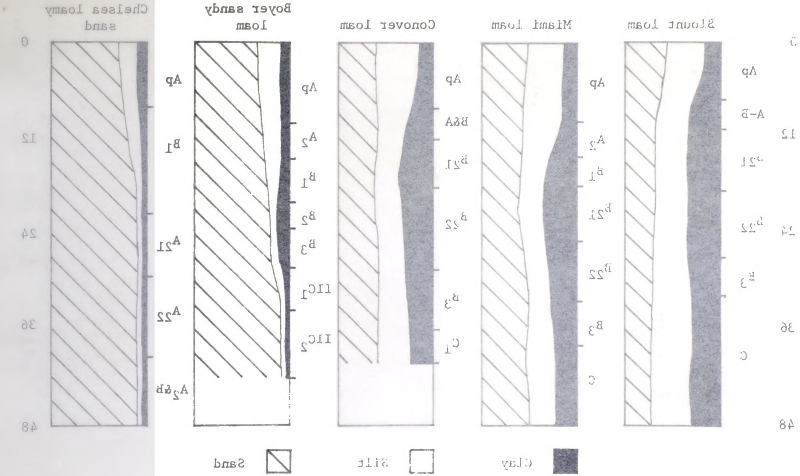

Fig. [illegible]. A schematic representation of particle size distribution in the soil profiles studied.

(1949) as modified by Day (1965). A textural-depth plot of the 5 profiles studied is given in Fig. 47. Numerical values for all analyses are given in the Appendix.

One of the most obvious relationships noticed in Fig. 47 is the balanced ratio of the particle classes - sand, silt, and clay - in the Blount, Miami, and Conover soils, and the preponderance of the sand component in the Boyer and Chelsea. An obvious inference here is that the first 3 would be suitable for most plant species while the last 2 would tend to be droughty. Conversely, septic tank drainfield systems should function well in the Boyer and Chelsea, although the possibility of ground-water contamination would be great.

A reasonably accurate model of a two-storied soil such as Metea loamy sand could be constructed by combining the upper 30 inches of Chelsea with the lower 18 inches of Miami. Here we can envision a profile rapidly permeable in the "upper story" but more slowly permeable in the "lower story." Rainfall would tend to infilter the upper story rapidly, but slow down at the contact zone. If a septic tank drainfield system were installed above the contact zone in Metea loamy sand, then the possibility of downslope movement of sewage effluent at the contact zone would be great.

Therefore, the importance of determining accurately the extent of Metea loamy sand inclusions in an area mapped Miami loam is apparent. Where these inclusions occur, a whole spectrum of different interpretations and recommendations would be required.

In addition to the previous interpretations, a couple of genetic inferences may be obtained from Fig. 47. First, the relative youth of the soils is confirmed by the lack of a pronounced

clay accumulation bulge in the B horizon. Second, there seems to be good evidence for a lithological discontinuity at about 20 inches in the Chelsea profile. The change in particle size distribution is nearly as marked as the one at 28 inches in the Boyer.

Bulk density of a soil is defined as the weight of soil per unit volume. Since it differs from particle density by including soil matrix voids (pores) in its measurement, as bulk density increases soil porosity usually decreases. Bulk density is usually greater in B horizons than in A horizons because of decreased organic matter content, decreased influence of roots, lack of the mechanical disturbance of cultivation, and the natural filling of pores by illuvial material from above. A sudden increase in bulk density in a soil profile usually indicates a sudden decrease in porosity and a horizon relatively impermeable or only slowly permeable to the movement of soil moisture.

In this study, bulk density was determined by the core method as outlined by Blake (1965, pp. 375-377). Cores 1 inch in thickness and 2 inches in diameter were used. Duplicate cores were taken for each horizon of each profile. These cores were used to determine moisture constants at low tensions before they were oven dried for bulk density measurements. Bulk density values between duplicate cores usually were within 5% of each other, and often closer.

Bulk densities of Ap and B_2 horizons are plotted in relation to clay and sand content in Figs. 48A, 48B, 49A, and 49B. On the whole, the finer textured soils had greater bulk densities than the coarser textured soils in both the Ap and B_2 horizons. This is contrary to the general belief that sandy soils have higher bulk

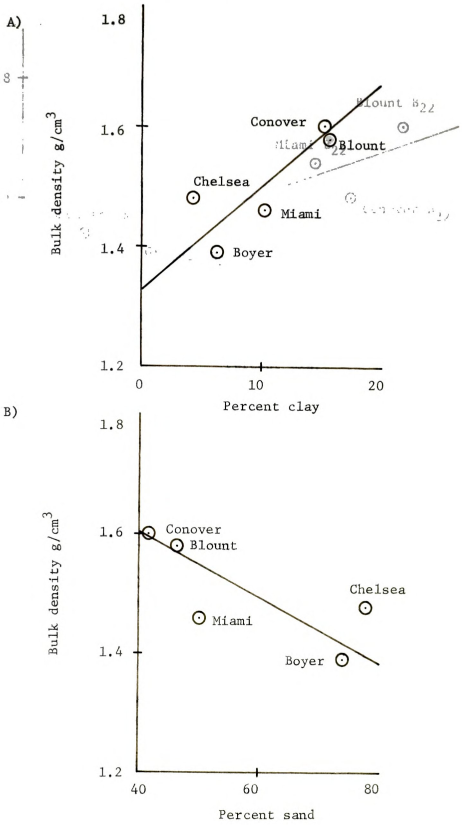

Fig. 48. Bulk density of Ap horizons as a function of clay and sand content.

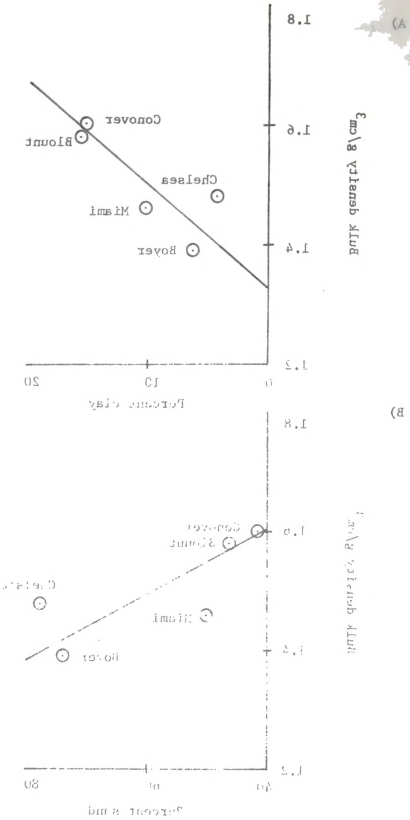

Fig. 58. Bulk density of [illegible] horizon as a function of clay and sand content.

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densities than clay loams (Buckman and Brady, 1969, p. 53). The author of this dissertation was amazed by the loose consistence of Boyer and Chelsea when he was sampling them. Perhaps this looseness influenced the trends.

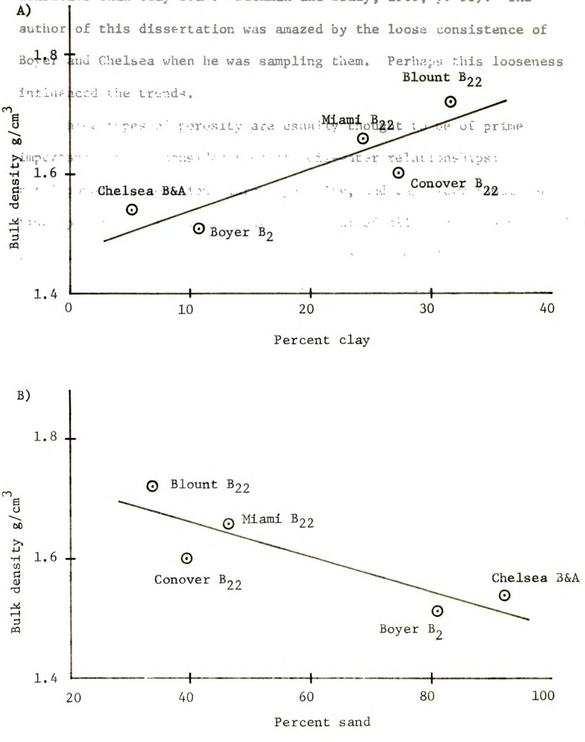
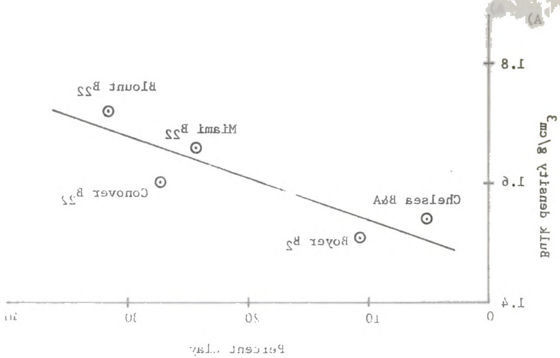


Fig. 49. Bulk density of B_2 horizons as a function of clay and sand content.



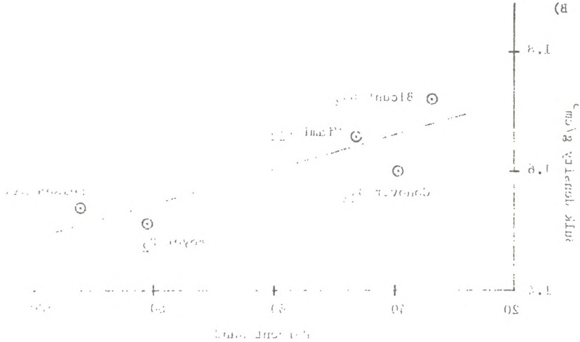


Fig. 49. Bulk density of B horizons as a function of clay and sand content.

densities than clay loams (Buckman and Brady, 1969, p. 53). The author of this dissertation was amazed by the loose consistence of Boyer and Chelsea when he was sampling them. Perhaps this looseness influenced the trends.

Three types of porosity are usually thought to be of prime importance in the consideration of soil-water relationships; total porosity, aeration (large) porosity, and capillary (small or fine) porosity. Total porosity is the sum of all voids in a unit volume of soil. Fine porosity is that group of pores in which is stored plant-available moisture and which will retain water against a tension equivalent of 1/3 atmosphere up to a tension equivalent of 15 atmospheres (Kohnke, 1968, pp. 56-57). Aeration porosity in this study is considered that porosity which is exhausted of water between saturation and a tension equivalent of 1/3 atmosphere.

Moisture desorption levels were obtained by extracting moisture from soil cores at a tension equivalent of 1/3 atmosphere and from fragmented soil samples at a tension equivalent of 15 atmospheres using the pressure-plate technique as outlined by Richards (1965, pp. 128-137). Porosity values were calculated using the procedure of Vomocil (1965).

Porosity values for Ap and B_2 horizons are plotted in relation to clay and sand content in Figs. 50A, 50B, 51A, and 51B. In the Ap horizons large porosity values were uniformly low at about 5-10%, with no apparent trend. Small porosity varied from about 35-40% and total porosity from about 40-47%, with an apparent inverse relationship to clay content. In the B_2 horizon large porosity again is very low, except for the Boyer sample which

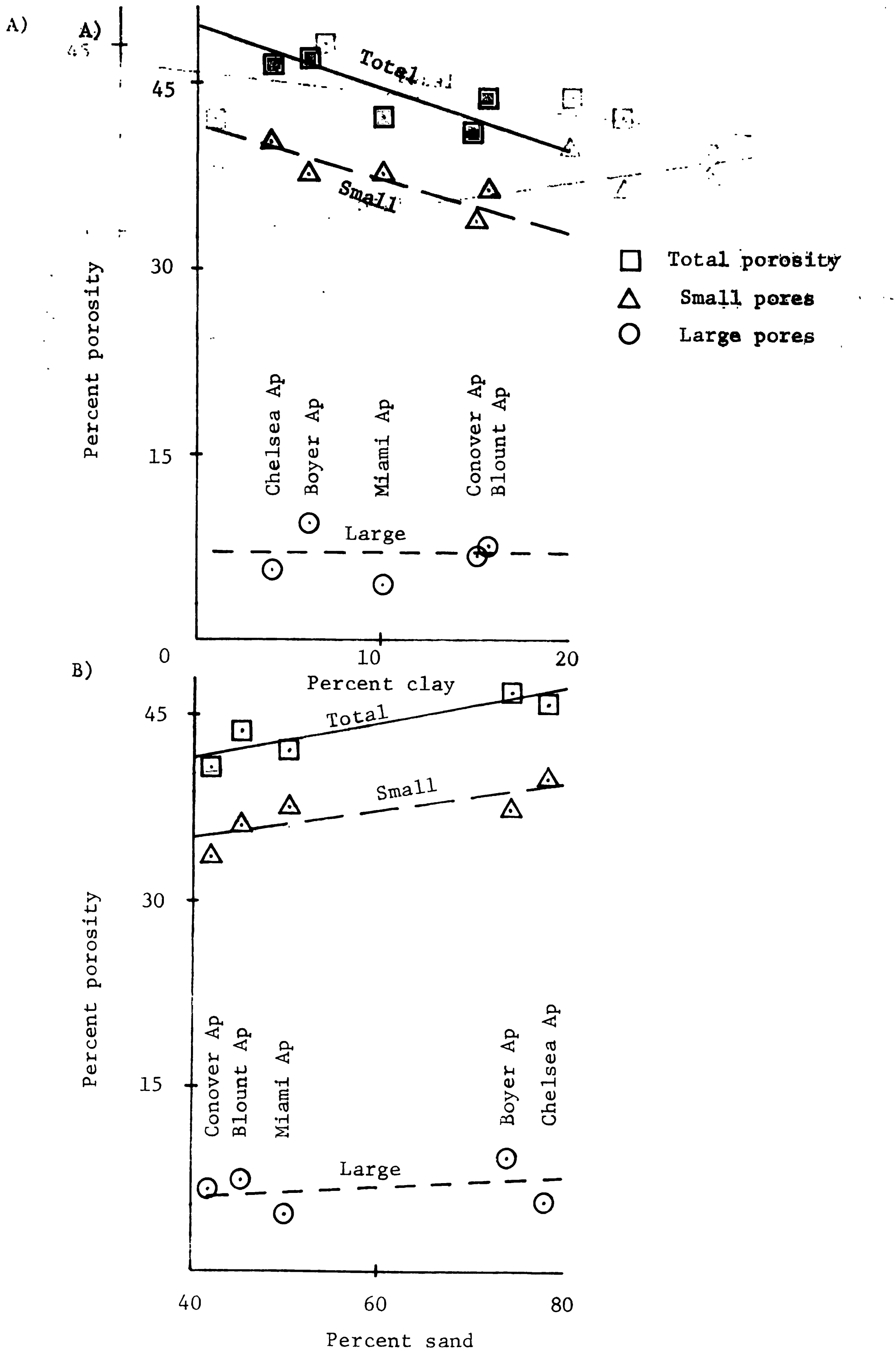


Fig. 50. Porosity in Ap horizons as a function of clay and sand content.

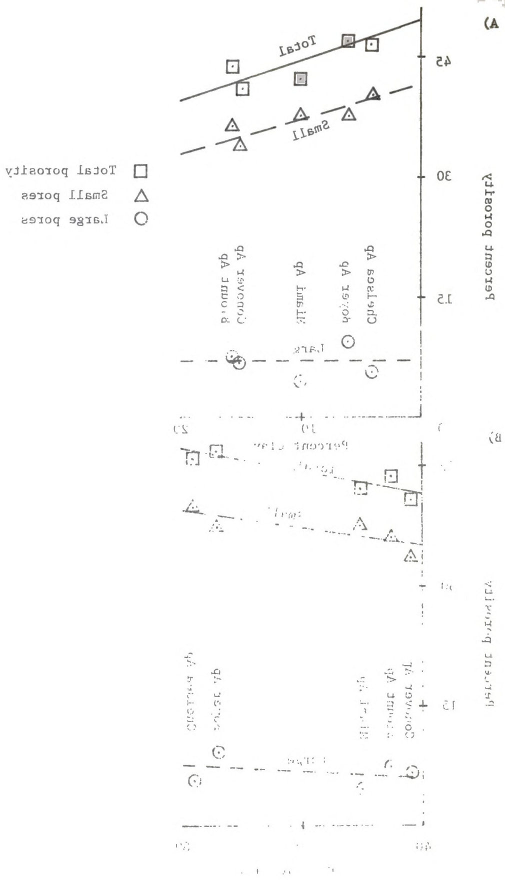

A)
B)
Total
Small
Large
Total porosity
Small pores
Large pores
Percent porosity
Percent clay
Chelsea Ap
Hoyer Ap
Miami Ap
Conover Ap
Blount Ap
45
30
15
10
20

Fig. 10.

approaches the small porosity value. As a general rule, the sandier soils are thought to be dominated by large pores. Removing the Boyer influence, however, leaves a group of points with no general trend except that large porosity seems low and small porosity high. One [illegible] movement of water [illegible] the B horizons [illegible]

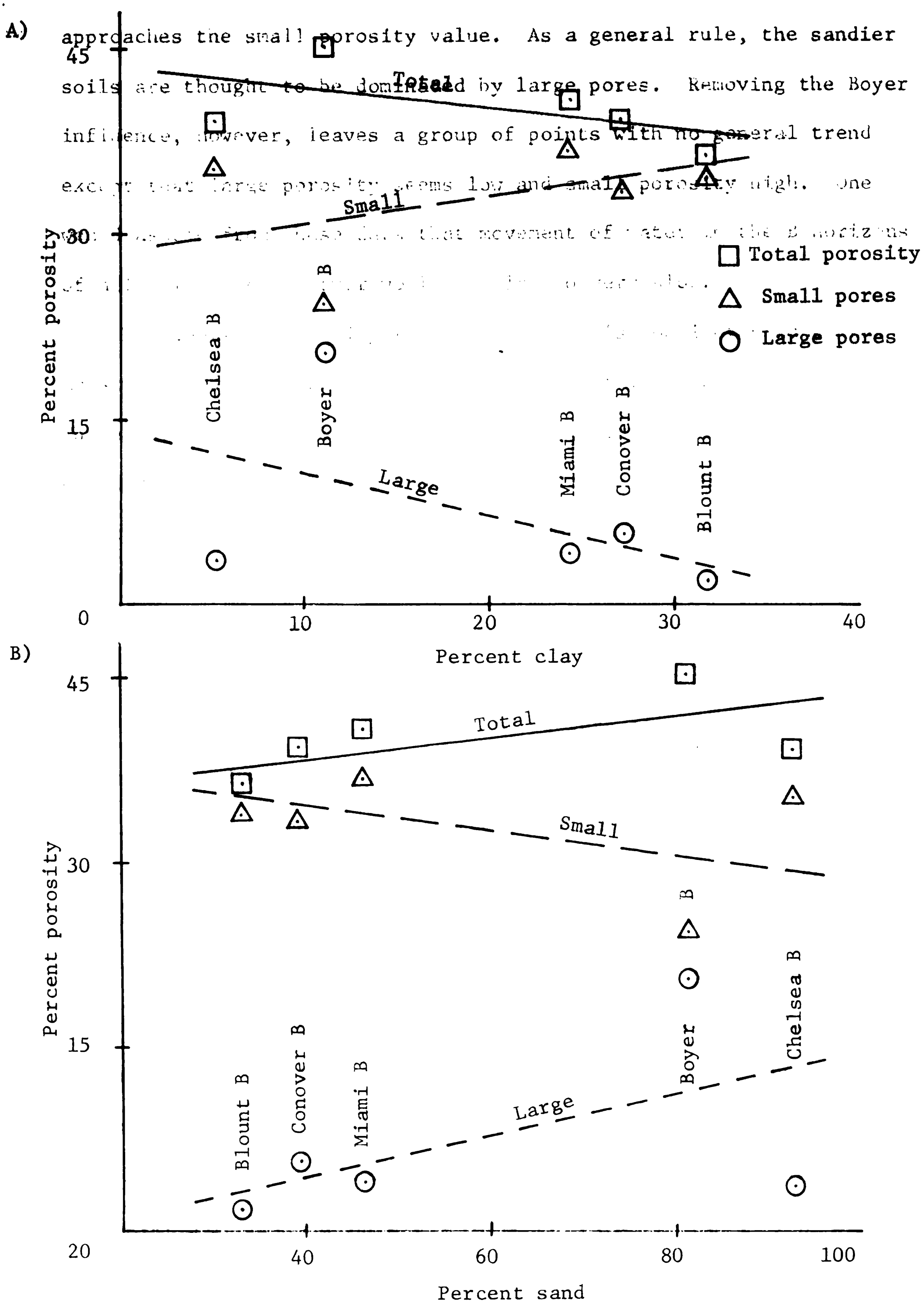


Fig. 51. Porosity in B_2 horizons as a function of clay and sand content.

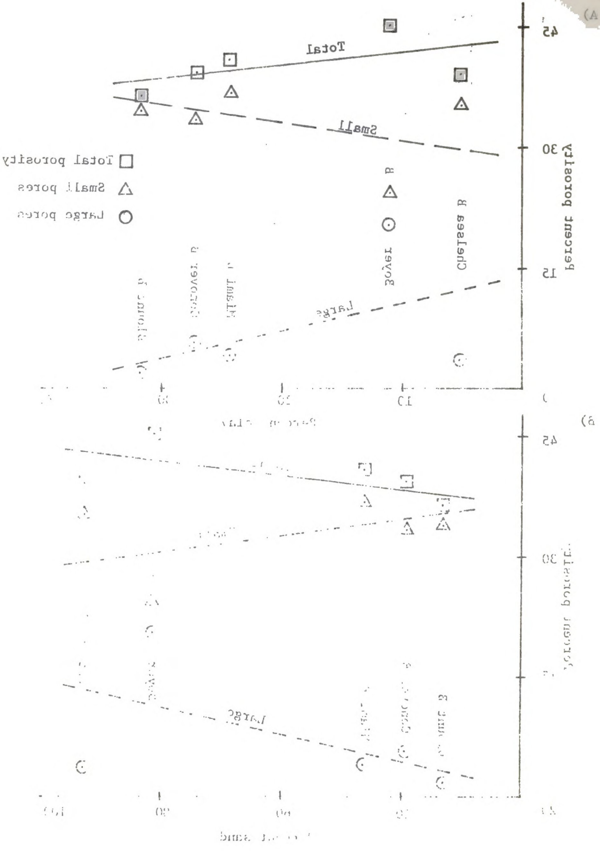


Fig. 51. [illegible] a function of clay and sand content.

approaches the small porosity value. As a general rule, the sandier soils are thought to be dominated by large pores. Removing the Boyer influence, however, leaves a group of points with no general trend except that large porosity seems low and small porosity high. One would assume from these data that movement of water in the B horizons of all soils except Boyer would be slow to very slow.

Plant-available moisture in this study is considered to be the moisture held between a tension equivalent of 1/3 and 15 atmospheres. These values are plotted for the Ap and B_2 horizons as a function of clay and sand in Fig. 52A and 52B. For the Ap, Chelsea and Boyer are low at 5% and 7% while the others are in much better shape at 13% to 14%. In the B_2 horizons, Chelsea is very low at 3%-4%, Blount is surprisingly low at 6%, Miami and Conover about medium at 8%, while Boyer is surprisingly high at 9%. Apparently the slight clay bulge in the Boyer B_2 in Fig. 47 is very significant. The author noticed when working with Boyer something that was common knowledge among Michigan soil surveyors - the Boyer B is "sticky." Apparently there is a relationship here that has not been adequately investigated.

There is a strong direct relationship between plant-available moisture and clay content in the Ap, but no real trend in the B_2 because of the disparity between Chelsea and Boyer, the sandy members.

Many of those who work with soil moisture research in Michigan feel strongly that the difference between soil moisture content at tensions of 1/3 and 15 atmospheres does not accurately represent plant-available moisture in sandy soils such as Boyer and Chelsea.

They consider these values too low and prefer using the difference between .06 and 15 atmospheres as plant-available moisture.

When varying the criteria in the comparison of soils, one is forced to make the arbitrary decision as to when the criteria will be changed. In this study the change was made at the textural break between sandy loam and loamy sand. Plant-available moisture values were calculated for Boyer and Chelsea using both .06 and 1/3 atmospheres tension along with the 15 atmosphere tension value.

A comparison of the original and recalculated plant-available moisture values is given below:

Soil	Horizon	Plant-available moisture 1/3 - 15 atmospheres	.06 - 15 atmospheres
Boyer	B_2	9.4	12.2
Chelsea	Ap	5.2	24.6
Chelsea	B&A	3.6	17.5

Since the recalculated values would have given Chelsea approximately 2/5 greater plant-available moisture in the Ap and 3/5 greater plant-available moisture in the B than Miami, they are given for purpose of comparison only and are not plotted in Fig. 52.

An even more striking comparison is that obtained when plant-available moisture is expressed as inches per profile.

Soil	Plant-available moisture (inches/48-inch profile) 1/3 - 15 atmospheres	.06 - 15 atmospheres
Blount	5.81	-
Miami	6.82	-
Conover	6.55	-
Boyer	2.73	5.49
Chelsea	2.42	17.58

The recalculated values would indicate that the upper 48-inch profile of Chelsea would have 3 times the plant-available moisture of the upper 48 inches of Miami. Since this seemed highly unlikely, the 1/3 - 15 atmosphere values were used throughout for plant-available moisture.

From these analyses Chelsea is a confirmed droughty soil, this pedon of Boyer has a remarkable moisture reserve in the B_2, and this pedon of Blount is surprisingly low in plant-available moisture storage potential in the B_{22}.

Swelling potential of a soil is a measure of its tendency to increase in volume upon wetting. It is a parameter attracting increasing attention because of its application to location and design of foundations for light buildings, roads, airport runways and other structures not necessarily footed on bedrock. In this study, the swelling potential of the B_2 horizons was determined by the method of Lambe (1960).

These determinations were plotted against clay content in Fig. 53. Chelsea had practically no swelling tendencies, Boyer was weak, Miami and Conover were almost identical and much higher than the others, although still below the critical range. Blount, although 6% higher in clay than Miami or Conover, was 300 lbs./ft.^{2} lower in swelling potential. This suggests a slightly different clay mineral suite in Blount than in Miami and Conover, which is indicated in the mineralogical family placement of Blount as illitic and Miami and Conover as mixed in the official series descriptions.

While buildings with shallow footings should never have problems from swelling soil when constructed in Chelsea or Boyer,

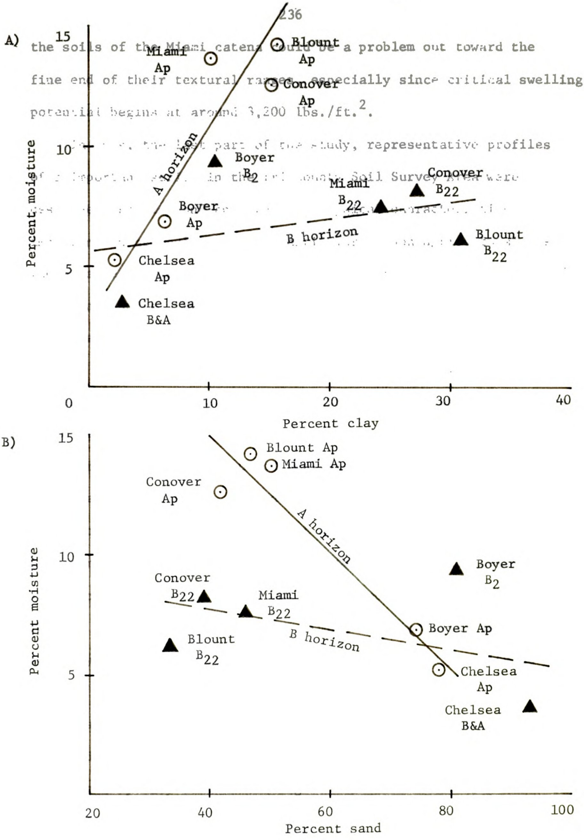


Fig. 52. Available moisture as a function of clay and sand content.

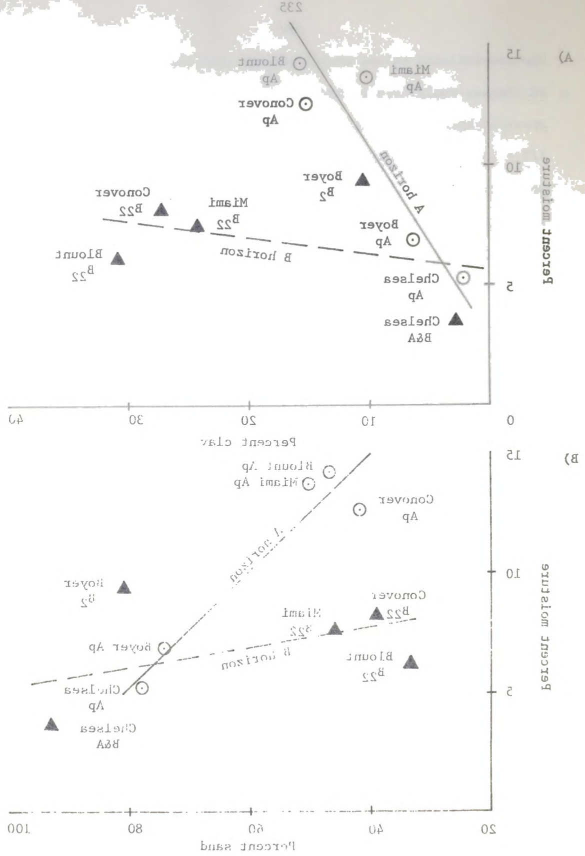


Fig. 52. Available moisture as a function of clay and sand content.

the soils of the Miami catena could be a problem out toward the fine end of their textural ranges, especially since critical swelling potential begins at around 3,200 lbs./ft.^{2}.

In this, the last part of the study, representative profiles of 5 important series in the Tri-County Soil Survey Area were described, sampled and analyzed for physical characteristics important in agricultural and, particularly, non-agricultural use. These series varied in texture almost the extent of the spectrum of Tri-County soils. By using these 5 profiles as building blocks, nearly every soil in the area could be duplicated to a reasonable degree. Likewise, by extrapolation of the characteristics of these profiles, the approximate characteristics of most soils of the area could be derived.

Particle size distribution analysis yielded textures ranging from clay loam to sand. Bulk density of Ap and B_2 horizons was found to increase with clay content and decrease with sand, which is contrary to what is generally expected. In porosity measurements, large porosity was low for Ap and B_2 horizons of all soils except for the Boyer B_2 which had about as much large porosity as small porosity. There were no strong trends relating any porosity to clay or sand content in either horizon.

Plant-available soil moisture of the Ap horizons increased with clay and decreased with sand. Swelling potential was strongly influenced by clay content although the maximum values did not reach the critical level in these soils.

The purpose of this section was to determine indices of physical characteristics of soils which might occur as inclusions in

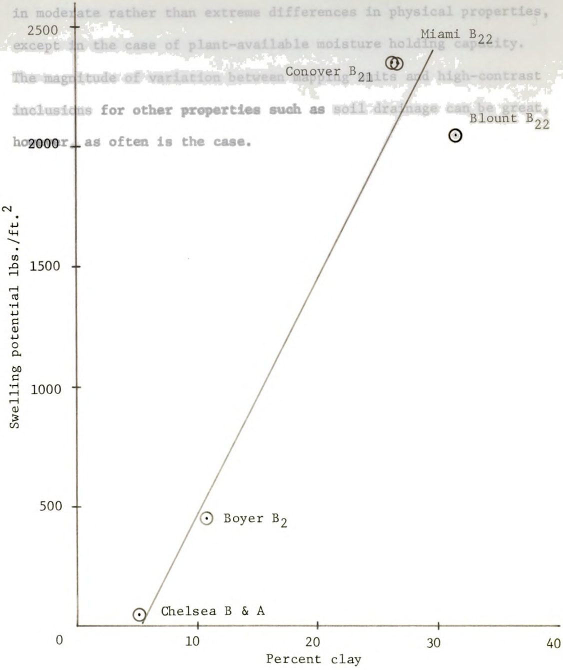


Fig. 53. Swelling potential in B horizons as a function of clay content.

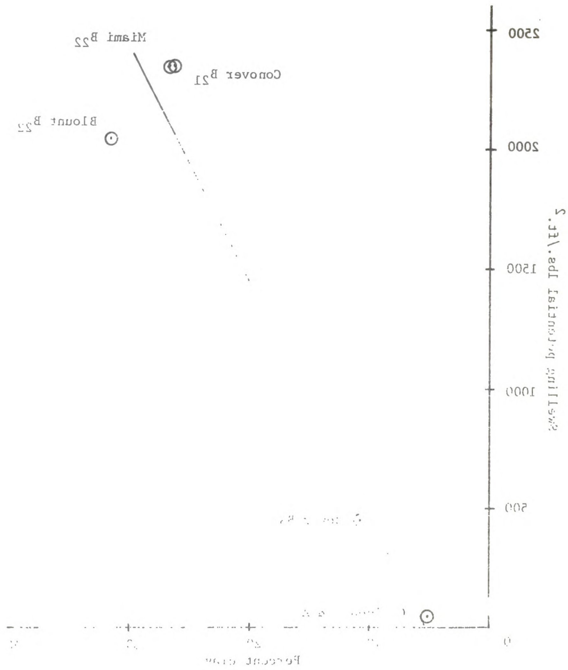


Fig. 53. Swelling potential [illegible] as a function of [illegible]

mapping units carrying another designation. It seems that even inclusions of highest contrast in the Tri-County Area would result in moderate rather than extreme differences in physical properties, except in the case of plant-available moisture holding capacity. The magnitude of variation between mapping units and high-contrast inclusions for other properties such as soil drainage can be great, however, as often is the case.

VI. SUMMARY AND CONCLUSIONS

A. SUMMARY

In the beginning we have tried to trace the evolution of the soil survey in the United States from its inception to its present form. By citation of example, we concentrated on the state of knowledge of soil classification at successive periods from the 1900's to the 1960's. We emphasized the progression of methods of soil survey and the evolution of taxonomic unit definitions with the development of morphological descriptive technique. Particular emphasis was given to the concept of the mapping unit and how well these units were defined. Interpretations drawn from the survey information were outlined and discussed, and the soil maps were examined for amount of detail and relation of detail to geological, topographical, and political boundaries.

Theoretically, a natural system of soil classification should be independent of any use to which the system may be put. Yet there are repeated references in manuals and guides cautioning that the soil survey must be planned carefully, with the proposed use in mind, to allow for proper mapping scale, intensity of detail, and degree of interpretation. In fact, the composition of the mapping unit itself is influenced by the anticipated use to which the survey will be put. One has but to compare the mapping unit of a reconnaissance soil survey with the mapping unit of a soil-platt map for a proposed subdivision to be convinced that this is true.

Since no guides could be found to differentiate the nature of agricultural and non-agricultural soil surveys, we chose an inductive approach of contrasting contemporary surveys of areas

obviously urbanizing with other surveys of areas scarcely touched by population growth or industrial development. The results of this study revealed no major differences between these groups of surveys. Therefore, we must assume an urban soil survey is an urban soil survey in name only, and that any contemporary survey may be examined to determine its suitability for non-agricultural planning purposes.

The use of "non-agricultural" soil surveys as an aid in planning is an avowed purpose for making such surveys. Even so, there is much disagreement as to the kind of information and the amount of detail desired by planners. A critical factor here is the definition of planning; is land-use planning the construction of a regional land-use plan or is it the evaluation of a small parcel of land for soil suitability for septic tank drainfield systems? Planners like to summarize each planning parameter on a separate chart and would like to relegate only one chart to the soils parameter. In reference to soil suitability for urbanization, however, several charts may be needed to best express soil suitability for various uses (McHarg, 1969).

The specificity of soils information about an area and detail of delineation shown within the area is supposed to be dependent on the use to which the survey will be put. Obviously soils information needed to construct an equitable base for tax assessment can be more general than soils information needed for an engineering survey of a proposed interstate highway or a site evaluation for a multi-million dollar school complex. Perhaps an urban soil survey should strive for a compromise between these extremes.

Unfortunately, it is exceedingly difficult to convince users of

the soil survey that the delineated area includes something other than the taxonomic unit name it carries. It is even more difficult to convince users that a map containing impure delineations can be a valid map. Perhaps the best way to do this is by an accurate, concise, and clear definition of the mapping units within the survey area.

In an attempt to define with greater accuracy the contemporary "non-agricultural" soil survey, the author examined the Tri-County soil survey being conducted in Clinton, Eaton, and Ingham Counties in Michigan. These three contiguous counties include the cities of Lansing, the state capitol of Michigan, and East Lansing, the home of Michigan State University. A sizeable portion of the cost of this survey was defrayed by the local governments so that the soils information would be available for non-agricultural planning purposes. Since the metropolitan population numbered in excess of 150,000 at the instigation of the soil survey, one could assume there would be no place in any of the three counties immune to the influence of urban development within the two decades following the completion date of the survey. For these reasons the Tri-County soil survey merited the designation "urban soil survey."

During the summers of 1965, 1966, and 1967, the author worked in the Tri-County soil survey as a mapper and a supervisor of Michigan State University student mappers. In addition, he carried out a research program in an attempt to define and evaluate some of the parameters associated with a detailed progressive soil survey, especially one to be used as a basis for urban development. He conducted a seven-phase investigation, the parts of which are listed

below:

1. Mapping unit analysis - Twelve of the mapping units of the Tri-County Soil Survey Area were analyzed by the point-intercept transect method. The results of these analyses indicated how well the survey was actually measuring what it was supposed to measure.
2. Standard quarter-section mapping analysis - The mapping efforts of 5 of the Tri-County soil surveyors were evaluated, along with a 1952 detailed soil survey and the 1933 Ingham County soil survey. These mapping samples covered a typical quarter-section and were evaluated against gridded observations which had been examined in detail, classified, and recorded.
3. Effect of mapping scale on map accuracy - The four quadrants of a quarter-section were mapped by the same operator, with each quadrant at a different mapping scale. Survey time varied only as needed to investigate the additional landscape areas the larger mapping scales made apparent.
4. Morphological descriptions of two soil profiles by several operators - Exposures of two different soil profiles were described by 6 operators to determine how closely they evaluated an array of morphological characteristics and combined them into a description of the soil individual.
5. Evaluation of soil texture by several operators - Of all soil morphological characteristics approximated in the field, texture is one of the most fundamental. To measure the precision of textural evaluation among operators, a laboratory exercise involving 20 soil samples and 8 soil surveyors was conducted.

6. Comparison of the conceptual range of the Conover series as envisioned by three operators - Three soil surveyors selected three pedons each of the Conover series to represent the modal individual and the extreme upper and lower limits of the series from the standpoint of the drainage parameter. These pedons were sampled and described by the author, and the descriptions were compared to the official series description to evaluate differences in operator concept of the range of the Conover series.
7. Comparison of physical properties of 5 important Tri-County soil series - Soil physical properties important to land use and development, especially for non-agricultural purposes, were determined for representative pedons of 5 important series mapped in the Tri-County Soil Survey Area. These series nearly spanned the range of textural variation found within the area, and knowledge of their properties would serve as an index of physical contrast to evaluate mapping unit inclusions.

B. CONCLUSIONS

The urban soil survey is a figment of the imagination. It exists as a distinct entity only in the minds of those members of the National Cooperative Soil Survey engaged in surveys they call urban, and in the minds of members of local funding, planning, and other governmental bodies concerned with the procurement and use of soil survey information. There are a number of detailed, progressive soil surveys of urbanizing areas planned, in progress, or completed in the decade of the 1960's that are called urban soil surveys. In no discernable way other than funding do they differ from agricultural soil surveys of the same period.

Soil survey is the application of soil taxonomy and pedology to a geographical area to produce a soil map and the accompanying soil survey report defining soils, geology, land form, and cultural features of the area. It should include the most recent research information along with suggested use and management of the soils identified and mapped within the area. In addition to the scientific and technical information used in making a soil survey, a number of subjective and arbitrary decisions are involved. It is impossible to remove certain elements of art from the soil survey.

The science of soil classification has made tremendous strides within the twentieth century. The art of soil survey has scarcely kept pace. With the advent of the <u>7th Approximation of a System of Soil Classification</u> and its adoption as the official classification system of the National Cooperative Soil Survey, a growing trend toward stricter definition of taxonomic units and the proliferation of soil series has been observed. Mapping unit definitions, however, have been sadly neglected in many contemporary "urban soil surveys." These modern mapping unit definitions, on the whole, are decidely inferior to those found in the good soil survey of the 1930's.

This state of affairs - the progressive refinement of taxonomic unit (soil series) definitions and the deterioration of the concept of the mapping unit - has resulted in mapping units of decreasing homogeneity until the 1952 standard of 15% for allowable inclusions in mapping units, if applied today, would often represent that portion of the unit occupied by the so-called "major component" of the unit.

Since no official set of mapping unit descriptions existed in

the Tri-County soil survey at the time this study was made, one must assume the mapping unit consisted of the assigned taxonomic-unit name plus up to 15% unnamed inclusions allowed at that time. A detailed examination of 12 major mapping units in Clinton County, Michigan, found them to contain from about 22% to 98% inclusions at the phase of series level and 22% to 95% at the series level. Unless these units are carefully defined in the Tri-County Soil Survey Report, the value of the report will be adulterated at least to the extent of the inclusions present within the mapping units of the area.

A major portion of this work considers the abilities and techniques of the individuals making the soil survey. They exhibited a fair degree of precision when evaluating one parameter such as soil texture. This agreement among individuals deteriorates rapidly as parameters and permutations of these parameters increase. As they progress from soil texture, to profile description, to definition of the range of a taxonomic unit (soil type), to the construction of a soil map, agreement among individuals declines rapidly. There seemed to be little relationship between proficiency and years of experience among <u>competent</u>, <u>trained</u> soil surveyors at any level of generalization, from evaluation of soil texture to construction of the soil map.

While variation among physical properties of Tri-County soils is not as great as in some areas, there is sufficient variation to cause complications of a serious magnitude if many of the mapping unit inclusions are subjected to the same use and management as the component for which the mapping unit is named. In essence, most Tri-County mapping units are soil complexes and should be treated as such.

Therefore, accurate, quantitative definitions of the mapping units, preferably by the point-intercept transect method, are mandatory.

Since increasing mapping scale and time expended on mapping did not materially improve the quality of the soil maps, the fault must lie in the dichotomy between taxonomic units and mapping units. Much time and effort could be saved in future soil surveys - both "agricultural" and "urban" - by accurate, quantitative definition of mapping units early in the survey, with revisions as the survey progresses. And, in areas of urbanization, the problem of highly detailed surveys and evaluation of small land areas can only be resolved by the use of a competent, interpretive soil scientist.

When an interpretive soil scientist examines a small area of land - from a fraction of an acre to several hundred acres - he is reclassifying and remapping the soils of the area. This is a task which will never be completed so long as man continues to use the land.

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APPENDICES

APPENDIX A

APPENDIX A

STANDARD SOIL DESCRIPTION ABBREVIATIONS

Horizons

0 - **Organic horizons of mineral soils**

0_1 - **Original form of vegetation recognizable**
0_2 - **Original form of vegetation not recognizable**

A - **Upper eluvial horizon**

A_1 - **Humified organic matter enrichment**
A_2 - **Clay, Fe, or Al emigration**
A_3 - **A-B transition, more like A**
AB - **Upper like A, lower like B**
A&B - **Resembles A_2 with minor component of B**

B - **Lower illuvial horizon**

B_1 - **A-B transition, more like B**
B_2 - **Strongest expression of B characteristics**
B_3 - **B-C transition**
B&A - Resembles B with minor component of A_2

C - Partially weathered, cemented, gleyed, or with accumulation of Ca or Mg carbonates or more soluble salts

R - Underlying bedrock

II,III, etc. - Lithologic discontinuity

' - Lower sequm of bi-sequal soil (when used as horizon superscript)

Subhorizons

b - buried
ca - carbonate accumulation
cn - concretions
g - strong gleying
h - illuvial humus
ir - illuvial iron
m - strong cementation, induration
p - plowing, disturbance
t - illuvial clay
x - fragipan character

STANDARD SOIL DESCRIPTION ABBREVIATIONS (Cont.)

Horizon Boundary

Distinctness

a - abrupt (<1 in. or <2.5 cm.)
c - clear (1 - 2 1/2 in. or 2.5 - 6.5 cm.)
g - gradual (2 1/2 - 5 in. or 6.5 - 13 cm.)
d - diffuse (>5 in. or >13 cm.)

Topography

s - smooth (planar)
w - wavy (pockets wider than deep)
i - irregular (pockets deeper than wide)
b - broken (intermittent)

Color

10YR - hue (spectral color)
4/ - value (brightness)
3 - chroma (saturation)

Mottling

Abundance

f - few (<2%)
c - common (2-20%)
m - many (>20%)

Size

1 - fine (<5 mm)
2 - medium (5-15 mm)
3 - coarse (>15 mm)

Contrast

f - faint (barely seen)
d - distinct (readily seen)
p - prominent (conspicuous)

Texture

g - gravel
vcos - very coarse sand
cos - coarse sand
s - sand
fs - fine sand
vfs - very fine sand
lcos - loamy coarse sand
ls - loamy sand
lfs - loamy fine sand
sl - sandy loam
fsl - fine sandy loam
vfsl - very fine sandy loam
gsl - gravelly sandy loam
l - loam
gl - gravelly loam
stl - stony loam
si - silt
sil - silt loam
cl - clay loam
sicl - silty clay loam
scl - sandy clay loam
stcl - stony clay loam
sic - silty clay
c - clay

STANDARD SOIL DESCRIPTION ABBREVIATIONS (Cont.)

Structure

Size	Granular	Blocky	Prismatic (horizontal dimension	Platy (vertical dimension)
		(in millimeters)		
vf - very fine	<1	<5	<10	<1
f - fine	1-2	5-10	10-20	1-2
m - medium	2-5	10-20	20-50	2-5
c - coarse	5-10	20-50	50-100	5-10
vc - very coarse	>10	>50	>100	>10

Distinctness

0 - structureless
1 - weak
2 - moderate
3 - strong

Form

pl - platy
pr - prismatic
abk - angular blocky
sbk - subangular blocky
gr - granular
sg - single grain
m - massive

Consistence

Wet soil

Stickness

wso - nonsticky
wss - slightly sticky
ws - sticky
wvs - very sticky

Plasticity

wpo - nonplastic
wps - slightly plastic
wp - plastic
wvp - very plastic

Moist soil

ml - loose
mvfr - very friable
mfr - friable
mfi - firm
mvfi - very firm
mefi - exceedingly firm

Dry soil

dl - loose
ds - soft
dsh - slightly hard
dh - hard
dvh - very hard
deh - extremely hard

STANDARD SOIL DESCRIPTION ABBREVIATIONS (Cont.)

Effervescence
(with hydrochloric acid)

e - slight
es - strong
ev - violent

Concretions

conca - calcium
conir - iron
consi - silica

APPENDIX B

APPENDIX B

MAPPING LEGEND
October 1966

TRI-COUNTY SOIL SURVEY

Carlisle muck M010 A1
Rifle muck M011 A1
Rifle peat P011 A1
Markey muck M013 A1
Edwards muck M015 A1
Warners muck M016 A1
Linwood muck M025 A1
Houghton muck M030 A1
Palms muck M032 A1
Adrian muck M035 A1
Tawas muck M060 A1
Kerston muck M070 A1

Oakville loamy sand 1392 B1 (0-6%), C1
Oshtemo loamy sand 2182 B1
Oshtemo sandy loam 2183 B1, C1
Bronson sandy loam 2283 A1, B1
Spinks loamy sand 2342 A1, B1, C1, C3, D1, D3
Ottawa loamy sand 2402 B1 (0-6%), C1
Excavated sand 2411
Excavated sand (resurfaced) 2415
Berrien loamy sand 2482 B1 (0-6%)
Perrin loamy sand 2532 A1, B1
Perrin sandy loam 2533 A1, B1
Boyer loamy sand 2552 A1, B1, C1, D1

CLINTON COUNTY

Excavated loams 4525
Excavated loams (resurfaced) 4535
Celina sandy loam 5353 A1, B1
Celina loam 5355 A1, B1, B2
Tuscola loam 5365 A1, B1
Tuscola silt loam 5366 B1

Kibbie loam 6305 A1, B1
Kibbie silt loam 6306 A1, B1
Blount loam 6405 A1, B1
Blount silt loam 6406 A1, B1
Conover loam 6455 A1, B1
Teasdale sandy loam 6463 A1, B1
Locke sandy loam 6473 A1, B1
Wasepi sandy loam 6893 A1, B1
Matherton sandy loam 6943 A1, B1
Matherton loam 6945 A1, B1
Kibbie (coarse var.) loamy fine sand 7093 A1, B1
Spinks (somewhat poorly dr. var.) loamy sand 7352 A1, B1
Ottawa (somewhat poorly dr. var.) loamy sand 7512 A1 (0-6%)
Metea (somewhat poorly dr. var.) loamy sand 7592 A1, B1
Metamora sandy loam 7613 A1, B1

MAPPING LEGEND (Cont.)

TRI-COUNTY SOIL SURVEY

Boyer sandy loam 2553 A1, B1, C1, C3, D1, D3, E1, E3, F1
Metea loamy sand 2592 B1, C1

Fox sandy loam C3443 B1 cobbly phase
Fox sandy loam 3443 A1, B1, B2, C1, C2, C3, D1, D2, D3, E1, E3, F1, F3
Fox loam 3445 A1, B1, B2, C1, C2
Ionia sandy loam 3463 A1, B1
Ionia loam 3465 A1, B1
Owosso sandy loam 3493 A1, B1, B2, C1, C2, C3, D2
Hillsdale sandy loam 3603 B1, C2
Elmdale sandy loam 3623 B1, B2
Dryden sandy loam 3633 B1, B2
Lapeer sandy loam 3643 A1, B1, B2, C2, C3, D2
Sisson loam 4365 A1, B1, B2, C1, C2 D2, D3
Miami sandy loam 4503 B1, B2, C1, C2, C3, D1, D2, D3, E1, E2, E3
Miami loam 4505 A1, B1, B2, B3, C1, C2 C3, D1, D2, D3, E1, E2, E3, F1, F2, F3

CLINTON COUNTY

Granby loamy sand 8182 A1
Gilford loamy sand 8242 A1
Gilford sandy loam 8243 A1
Maumee loamy sand 8392 A1
Maumee sandy loam 8393 A1
Barry sandy loam 8553 A1
Corunna sandy loam 8613 A1
Corunna loam 8615 A1
Sebewa loam 8745 A1
Brookston loam 8805 A1
Pewamo loam 8815 A1
Pewamo clay loam 8817 A1
Lenawee silty clay loam 8848 A1
Colwood loam 8905 A1
Colwood silt loam 8906 A1

Washtenaw loams 9205 A1
Glendora loamy sand 9282 A1
Cohoctah sandy loam 9293 A1
Ceresco sandy loam 9473 A1
Shoals loam 9495 A1
Sloan loam 9595 A1
Wallkill loams 9605 A1

APPENDIX C

KEY TO SOILS OF TRI-COUNTY SURVEY AREA

June, 1964

<table>
<tr><th rowspan="2">Texture</th><th colspan="2">ONE-STORIED PARENT MATERIAL
Lithology</th><th rowspan="2">Color</th><th rowspan="2">Well Drained</th><th rowspan="2">Mod. Well Drained</th><th rowspan="2">Imperfectly Drained</th><th rowspan="2">Brunizem Transition</th><th rowspan="2">Humic-Gley</th></tr>
<tr></tr>
<tr><td rowspan="2">Clay loam to silty</td><td colspan="2">Shale and limestone Nonstratified.</td><td>Yellowish</td><td>MORLEY
5445 - 1
5446 - sil</td><td>MORLEY
5445 - 1
5446 - sil</td><td>BLOUNT
6405 - 1
6406 - sil</td><td></td><td>PEWAMO
8815 - 1
8818 - cl</td></tr>
<tr><td colspan="2">Stratified</td><td></td><td></td><td></td><td></td><td></td><td>LENAWEE
8848</td></tr>
<tr><td>Loam</td><td colspan="2">Sandstone and lime-stone.</td><td>Grayish to yellowish</td><td>MIAMI
4503 - sl
4505 - 1</td><td>CELINA
5355 - 1</td><td>CONOVER
6455 - 1</td><td></td><td>BROOKSTON
8805 - 1</td></tr>
<tr><td>Very fine sand, silt</td><td colspan="2">Sandstone and lime-stone.</td><td>Grayish to yellowish</td><td>SISSON
4363 - fsl
4365 - 1</td><td>TUSCOLA
5366 - sil
5365 - 1</td><td>KIBBIE
6305 - 1
6306 - sil</td><td></td><td>COLWOOD
8906 - sil
8905 - 1</td></tr>
<tr><td rowspan="2">Sandy loam</td><td colspan="2">Sandstone and lime-stone. Limy 18-42".</td><td>Yellowish</td><td>LAPEER
3643 - sl</td><td>DRYDEN
3633 - sl</td><td>LOCKE
6473 - sl
6475 - 1</td><td></td><td>BARRY
8553 - sl
8555 - 1</td></tr>
<tr><td colspan="2">Sandstone and limestone over 42" to lime.</td><td>Yellowish</td><td>HILLSDALE
3603 - sl</td><td>ELMDALE
3623 - sl</td><td>TEASDALE
6463 - sl</td><td></td><td>BARRY
8553 - sl
8555 - 1</td></tr>
<tr><td rowspan="2">Loamy sand and sand textural B.</td><td rowspan="2">Sand-stone, Lime-stone</td><td>Solum pH>5.8</td><td>Yellowish</td><td>SPINKS
2342 - ls
2343 - lfs</td><td></td><td>7352 - ls</td><td></td><td></td></tr>
<tr><td>Solum<5.8</td><td>Yellowish</td><td>COLOMA</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sand, fine sand, stratified.</td><td colspan="2">Sandstone, limestone</td><td>Yellowish</td><td>2093 - lfs</td><td></td><td>7093 - lfs</td><td></td><td>8093 - lfs</td></tr>
<tr><td rowspan="2">Sand (No textural B)</td><td colspan="2">Moderate limestone. pH solum>5.8.</td><td rowspan="2">Yellowish</td><td>OAKVILLE
1391 - s
1392 - ls</td><td>1382 - ls</td><td>7212 - ls</td><td></td><td>GRANBY
8182 - ls
MAUMEE
8393 - sl
8392 - ls</td></tr>
<tr><td colspan="2">Little or no lime-stone. pH solum<5.8</td><td>PLAINFIELD
1402 - ls
1401 - s</td><td>NEKOOSA
1412 - ls
1411 - s</td><td>MOROCCO
7451 - s
7452 - ls</td><td></td><td>NEWTON</td></tr>
</table>

KEY TO SOILS OF TRI-COUNTY SURVEY AREA (Cont.)

TWO-STORIED PARENT MATERIAL Texture, Upper Story	Texture, Lower Story	Well Drained	Mod. Well Drained	Imperfectly Drained	Brunizem Transition	Humic-Gley
Coarser upper story over finer lower story						
Sand to loamy sand, 18-42" thick.	Loam to silty clay	METEA 2592 - ls	METEA 2592 - ls	7592 - ls		
Sand to loamy sand, 42-66" thick.	Loam to clay	OTTAWA 2402 - ls	BERRIEN 2481 - s 2482 - ls	7512 - ls		GRANBY 8182 - ls MAUMEE 8392 - ls 8393 - sl
Loamy fine sand to fine sandy loam, 18-42" thick.	Loam to silty clay loam.	OWOSSO 3493 - sl		METAMORA 7613 - sl		8613 - sl 8615 - l
Sandy loam to loam, 24-42" (gravelly clay loam textural B)	Loam to silty clay loam.	KENDALL-VILLE 3723 - sl	CADMUS 3713 - sl	MACOMB 6603 - sl 6605 - l X6605 - l		BERVILLE 8495 - l
Finer upper story over coarser lower story						
Loam to silt loam, 42-66". (clay loam textural B)	Gravel and sand.	OCKLEY 4285 - l	THACKERY 4895 - l	SLEETH 6985 - l	LONGLOIS	WESTLAND 8725 - l
Loam to silt loam, 24-42" (gravelly clay loam B over 10" thick)	Gravel and sand less than 42" to lime.	FOX 3443 - sl 3445 - l C3445 - l	IONIA 3463 - sl 3465 - l	MATHERTON 6943 - sl 6945 - l	DRESDEN 3155 - l	SEBEWA 8745 - l
Sandy loam to silt loam 24-42". (gravelly clay loam B over 10" thick.)	Gravel and sand, more than 42" to lime.	KALAMAZOO	SUNFIELD		DOWAGIAC	SEBEWA 8745 - l
Loamy sand to sandy loam 24-42" (sandy clay loam part of B less than 10" thick.)	Sand and gravel. Less than 42" to lime.	BOYER 2552 - ls 2553 - sl	PERRIN 2532 - ls 2533 - sl	WASEPI 6893 - sl		GILFORD 8242 - ls 8243 - sl
Same as above.	Sand and gravel. More than 42" to lime.	OSHTEMO 2183 - sl 2182 - ls	BRONSON 2282 - ls 2283 - sl	BRADY 6722 - ls 6723 - sl	CONSTAN-TINE	GILFORD 8242 - ls 8243 - sl
Loamy sand to sandy loam, 10-24" (sandy clay loam B)	Gravel and sand. Less than 24" to lime.	CASCO		FABIUS		MUSSEY

KEY TO SOILS OF TRI-COUNTY SURVEY AREA (Cont.)

CLASSIFICATION OF ORGANIC & ALLUVIAL SOILS
JULY 1966

Soil Order					Intrazonal			
Great Soil Group					Organic Soils (Bog)			
Character of Organic Mat'l				Depth of Organic Mat'l				
					Shallow (12-42")			12"
*0 to 12"		12" to 42"	pH 12-24"	Deep over 42"	over sands	over loams	over marl	over marl
Woody	Deciduous	Dark brown, slightly to mod. decomposed over undecomposed brown fibrous	7.0 to 5.0	Carlisle M010	Tawas M060	Linwood M025	Edwards M015	Warners M016
Woody	Conifers & decid.	Brown to Yellow undecomposed fibrous	6.5 to 4.5	Rifle M011 P011				
Fibrous	Marsh	Dark brown yellow finely fibrous	7.0 to 6.5	Houghton M030	Adrian M035	Palms M032	Rollin M014	Warners M016
Fibrous	Marshland	Undecomposed over semi-fluid mass or water	7.0 to 5.0	Tahquamenon P095				

*The stage of decomposition of the surface 12 inches is reflected by the type name.

KEY TO SOILS OF TRI-COUNTY SURVEY AREA (Cont.)

CLASSIFICATION OF ALLUVIAL SOILS

Soil Order	Azonal			
Texture of Parent Material	Well Drained	Mod. Well Drained	Imperfectly Drained	Poorly to Very Poorly Drained
Loam to silt loam	Genesee 9393	Eel 933	Shoals 9495	Sloan 9595
Loamy fine sand to fine sandy loam	Landes 938		Ceresco 9473	Cohoctah 9293
Sand to loamy sand	Abscota 9362		Algansee 9462	Glendora 9282
Loam to silt loam, 18" to 42" over organ. soil				Wallkill 9605
Loam to silt loam, 18" to 42" over pr. dr. mineral soils				Washtenaw 9205
Alternate layers of organic & mineral soils (alluvial)				Kerston 071

APPENDIX D

Established Series
Rev. JD-FWS
5-17-67

APPENDIX D

BROOKSTON SERIES

The Brookston series is a member of the fine-loamy, mixed, non-calcareous, mesic family of Typic Argiaquolls. The Brookston soils typically have very dark gray silty clay loam A horizons 11 to 18 inches thick, gray mottled clay loam B horizons, and brown loam C horizons of calcareous glacial till.

Typifying Pedon: Brookston silty clay loam - cultivated field (Colors are for moist soil.)

Ap -- 0-8" -- Very dark gray (10YR 3/1) light silty clay loam; weak coarse granular structure; firm; cloddy when dry; many fine roots; neutral; abrupt smooth boundary. (7 to 10 inches thick.)

A12 -- 8-14" -- Very dark gray (10YR 3/1) silty clay loam, common fine faint dark yellowish brown (10YR 4/4) and dark gray (10YR 4/1) mottles; weak coarse subangular blocky structure breaking to moderate medium granular structure; friable; many roots; neutral; clear wavy boundary. (4 to 11 inches thick.)

B1gt -- 14-20" -- Dark gray (10YR 4/1) silty clay loam, common fine faint dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) mottles; moderate medium and coarse subangular blocky structure; firm; few fine roots; very dark gray (10YR 3/1) and gray (10YR 5/1) thin discontinuous clay films on ped faces and lining pores; neutral; clear wavy boundary. (4 to 10 inches thick.)

IIB21gt -- 20-31" -- Gray (N 5) clay loam, common fine distinct dark brown (10YR 4/3) and yellowish brown (10YR 5/4) mottles; moderate medium subangular blocky structure; firm; few 2-5 mm. pebbles; very dark grayish brown (10YR 3/2) filled root channels; very dark brown (10YR 2/2) silty clay loam material in old crayfish channels; dark gray (10YR 4/1) clay films on most peds and ling a few pores; neutral; gradual wavy boundary. (8 to 14 inches thick.)

BROOKSTON SERIES (Cont.)

IIB22gt -- 31-40" -- Gray (10YR 5/1) clay loam, many medium distinct yellowish brown (10YR 5/4 and 5/8) and dark yellowish brown (10YR 4/4) mottles; moderate coarse subangular blocky structure; firm; few roots in upper part; very dark gray (10YR 3/1) thin discontinuous clay films on ped faces; many pebbles; neutral; clear irregular boundary. (7 to 15 inches thick.)

IIB3 -- 40-46" -- Yellowish brown (10YR 5/6) and dark yellowish brown (10YR 4/4) clay loam, common medium distinct gray (10YR 5/1) mottles; weak coarse subangular blocky structure; firm; small irregular pockets of loamy material; many pebbles; neutral; clear irregular boundary. (4 to 12 inches thick.)

IIC -- 46-66" -- Brown (10YR 5/3) loam; structureless, massive; friable; dark yellowish brown (10YR 4/4) and brown (7.5YR 5/4) thin clay films along old root channels and worm holes; fingers of gray (10YR 5/1) and very dark gray (10YR 3/1) silty clay loam as fillings and linings of old krotovinas; moderately alkaline, calcareous.

Type Location: Howard County, Indiana; SW1/4NE1/4 sec. 5, T. 23 N., R. 4 E. 516 feet east of center line gravel road, and 345 feet south of ditch; 1/2 mile east of U.S. Hwy. 31, 1/3 mile south of U.S. Hwy. 35.

Range in Characteristics: The solum thickness generally ranges from about 30 to 50 inches but in some places it is as little as 24 inches. Mean annual soil temperature ranges from 49° to 57° F. The sola are commonly slightly acid to neutral, and some are mildly alkaline. The soil has as much as 20 inches of the upper part formed in loess. The A horizon is most commonly 12 to 16 inches thick, and it ranges from 11 to 18 inches in thickness. It is black (10YR 2/1) or very dark grayish brown (10YR 3/2) and loam or silty clay loam. Structure is weak to moderate, medium to coarse granular, or weak to moderate, fine to medium subangular blocky. Consistence is friable to firm. The B2 horizon ranges from 10YR through 5Y hue or is neutral (N), has value of 4 through 6, and chroma of 1 or 2. It contains few to common, faint to distinct mottles of 10YR or 7.5YR hue, value of 4 through 6, and chroma of 1 through 8. Clay films and organic coatings are very dark gray (10YR 3/1), or gray (10YR 5/1). Texture is commonly silty clay loam or clay loam and some subhorizons are loam. The upper 20 inches of the argillic horizon averages 27 to 35 percent clay and more than 15 percent fine or coarser sand. Structure is moderate, medium to coarse subangular blocky, moderate, medium to coarse angular blocky or weak to moderate, medium to coarse prismatic. Consistence ranges from friable to firm. The upper part of the B2 horizon commonly contains less sand than the lower part. Clay films in the Bt horizons range from easily seen on all peds and linings in pores to difficult to observe and only on some peds and linings in some pores. In some places, the B horizon is stony, and stones are on

the surface if they have not been removed. The number of stones is large enough to interfere with installing tile drains and with tillage. The C horizon has hue of 10YR or 2.5Y, value of 5 through 7, and chroma of 1 through 3. Texture is usually loam, but some is light clay loam or silt loam. Reaction is mildly to moderately alkaline, and the horizon is usually calcareous.

Competing Series and their Differentiae: Similar or related soils are in the Abington, Barry, Berville, Colwood, Drummer, Kokomo, Lenawee, Mahalasville, Marengo, Mermill, Millgrove, Navan, Patton, Pewamo, Ragsdale, Rensselaer, Sable, Virden, and Westland series. The Abington soils have thicker A horizons, and the lower part of the sola contain more gravel. The Barry soils have coarser texture in the B and C horizons. Berville soils have more gravel throughout the sola. The Colwood and Lenawee soils lack argillic horizons, have more variable texture in the sola, and formed in stratified materials. The Drummer soils have cambic horizons and contain less sand in the upper part of the sola. The Kokomo soils have thicker A1 horizons and finer textured B horizons. Mahalasville soils are low in sand in the upper part of the sola, and the lower part is loamy. The Marengo soils are more acid. The Mermill soils have coarser texture in the sola, and contain more gravel in the lower part. The Millgrove soils have gravelly sandy loam and gravelly sand C horizons. The Navan soils have coarser texture and contain more sand in the upper part of the sola, and have finer texture and contain less sand in the lower part. The Patton soils lack argillic horizons and the sola are low in sand. The Pewamo soils have finer texture in the B and C horizons. The Ragsdale soils have less sand in the sola. The Rensselaer soils contain more sand in the lower part of the sola, and they have stratified sand and silt in the C horizon. Sable soils lack argillic horizons, and the sola contain less sand. The Virden soils have higher chroma in the B horizon, and the C horizon is leached of carbonates. The Westland soils have more gravel in the lower part of the sola, and C horizons of calcareous gravel and sand.

Setting: These soils are on nearly level to slightly depressed topography. Slopes are less than 2 percent. The regolith is loamy glacial till of Wisconsin age. The climate is midcontinental type; summers are hot and winters are cold. The average daily maximum temperature in July is 88° F., and the average daily minimum temperature is about 22° F. in January. The mean annual soil temperature is between 47° and 59° F., and mean annual precipitation ranges from 30 to 44 inches.

Principal Associated Soils: The well drained Miami, moderately well drained Celina, somewhat poorly drained Crosby and Conover, and very poorly drained Kokomo, in a drainage sequence with the Brookston soils, are the most closely associated series.

Drainage and Permeability: Brookston soils are very poorly drained. Surface runoff is very slow to ponded; permeability is slow. Most areas are artificially drained by tile and open ditches.

BROOKSTON SERIES (Cont.)

Use and Vegetation: Mostly cultivated crops; crops are corn, soybeans, oats, wheat, and hay. Tomatoes, sugar beets, and field beans are important in some places. A small part is in permanent pasture or woodlots. Native vegetation was deciduous forest, and some swamp grasses and sedges.

Distribution and Extent: Indiana, southern Michigan, western Ohio and eastern Wisconsin. The series is extensive - more than 100,000 acres.

Series Established: White County, Indiana, 1915.

Remarks: The series was formerly classified as a Humic Gley soil. Parts of the soils now classified in the Barry, Hoytville and Pewamo series were formerly placed in the Brookston series. Soils formed in loess and associated with the Russell soils were formerly included in the Brookston series. Such soils are now considered to be within the range of the Ragsdale series. Part of the soils formerly placed in the Chalmers series are now considered within the range of the Brookston series. Relationships of the Della, Lear, Runnymede, and Kouts soils to the Brookston soils are not clear at the present time, but they are believed to not seriously conflict.

National Cooperative Soil Survey
U.S.A.

CELINA SERIES

The Celina series comprises moderately well drained Gray-Brown Podzolic soils developed in highly calcareous loam or silt loam, loam till, with a loess capping of less than 15 inches. Celina soils are the moderately well drained member of the drainage sequence that includes the well drained Miami, imperfectly drained (somewhat poorly) Conover, poorly drained Brookston, and the very poorly drained Kokomo soils. Morley soils have finer textured B2t horizons than Celina, and have clay loam or silty clay loam calcareous C horizons. Elmdale soils have coarser textured B2t horizons than Celina, and have calcareous, and sandy loam C horizons. Conover soils are also developed in calcareous loam or silt loam till, but are imperfectly drained, and have much thicker A1 horizons, or darker Ap horizons than Celina soils. Bremen soils are well drained with a more variable textured and thicker sola than Celina soils and Bremen soils are medium to strongly acid to depths of textured 42 to over 80 inches (sic).

Soil Profile: Celina silt loam

Ap 0-8" SILT LOAM; dark grayish brown (10YR 4/2) or dark gray (10YR 4/1); weak to moderate, medium granular structure; friable; slightly to medium acid; abrupt smooth boundary. 7 to 11 inches thick. In uncultivated areas the very dark gray (10YR 3/1) A1 is from 2 to 3 inches thick.

A2 8-11" SILT LOAM; brown (10YR 5/2) or yellowish brown (10YR 5/4); weak; medium, platy or weak, medium, granular structure; friable; medium to strongly acid; clear wavy boundary. 2 to 5 inches thick.

B1 11-14" FINE, SILT LOAM OR COARSE, SILTY CLAY LOAM; yellowish brown (10YR 5/4) or brown (10YR 5/3 - 4/3); moderate, fine to medium, subangular blocky structure; friable; medium to strongly acid; clear wavy boundary. 2 to 6 inches thick.

B21t 14-20" CLAY LOAM OR SILTY CLAY LOAM; dark yellowish brown (1)YR 4/4) or yellowish brown (10YR 5/4); moderate to strong, medium and coarse, subangular blocky structure; firm; thin to medium clay flows on numerous ped surfaces; medium to strongly acid; gradual wavy boundary. 3 to 10 inches thick.

B22t 20-24" CLAY LOAM OR SILTY CLAY LOAM; dark yellowish brown (10YR 4/4), mottled with yellowish brown (10YR 5/6) and grayish brown (10YR 5/2) mottle are common, medium and distinct; moderate to strong, coarse, subangular blocky structure; firm; medium acid. 2 to 12 inches thick.

CELINA SERIES (Cont.)

B23t 24-28" CLAY LOAM; dark brown (10YR4/3-7.5YR4/4) mottled with grayish brown (10YR5/2) and yellowish brown (10YR5/8); mottles are common, medium, and distinct; thin to thick dark reddish brown (5YR3/3), or dark brown (7.5YR3/2) clay coatings on numerous ped surfaces; moderate, medium to coarse, subangular blocky structure; firm, medium acid to neutral; abrupt irregular boundary. 1 to 8 inches thick.

C 28" LOAM OR SILT LOAM; yellowish brown (10YR5/4) or light olive brown (2.5YR5/4) mottled with pale brown (10YR6/3), mottles are common, medium, and distinct; massive to weak, coarse, subangular blocky structure; friable to firm; calcareous.

Range in Characteristics: The above profile is silter than the average Celina soils of Michigan. The depth to mottling ranges from 16 to about 40 inches. There is faint mottling in the B1 horizon, but with little or no mottling in the B21t. The loess capping is variable in short distances, ranging from 0 to 15 inches does occur in Michigan. The A2 horizon is very thin or absent in some areas. The B23t horizon is absent or discontinuous in some areas. The boundary between the B2 and C horizons is often irregular with tongues of B2 extending downward in an irregular and sometimes inverted pattern into the C horizon. In some areas, where the depth to calcareous till approaches the minimum, the sola is only slightly acid. The depth to calcareous till is from 20 to 42 inches. The C horizon is coarse, clay loam in some areas. Where Celina grades to Miami soils mottling occurs at the maximum depth. Where Celina grades into Conover soils the depth to mottling is the minimum, and the B1 horizon occasionally is grayish brown (10YR5/2). Silt loam and loam types have been mapped. Colors refer to moist conditions.

Topography: Nearly level to gently sloping areas in till plains and moraines. The dominant slope ranges from 1 to 6 percent.

Drainage and Permeability: Moderately well drained. Runoff is slow on the nearly level areas and moderate on the sloping areas. Permeability is moderate in the sola and moderately slow in the C horizon.

Vegetation: Deciduous forest, with oaks, sugar maple, and hickory as the prominent species.

Use: A large proportion of the Celina soils have been cleared. The principal crops grown are corn, wheat, oats, soybeans, clover, alfalfa, and to a lesser extent vegetables. Dairying is important in most areas. A relatively small proportion is in permanent bluegrass pasture and a smaller proportion is in woodlands.

Soil Management Group 2.5a

Distribution: Central-western and western Ohio, central and northern

CELINA SERIES (Cont.)

Indiana, and southern Michigan and possibly southeastern Wisconsin.

Type Location: 1500 feet southwest from Glass road; 1 mile southeast from Ohio Route 729, Fayette, County, Ohio.

Series Established: Clark County, Ohio, 1949.

Source of Name: County seat of Mercer County, Ohio.

Remarks: In Michigan Celina soils were formerly included with either Miami or Conover soils.

HAM - OCR
4/27/59 National Cooperative Soil Survey - U.S.A.

ORDER: Alfisol

SUBORDER: Udalf

GREAT GROUP: Normudalf

SUBGROUP: Typic normudalf

FAMILY: Fine loamy, mixed, mesic

Established Series
Rev. RID-JDH-FFR-TEF
3-68

CHELSEA SERIES

The Chelsea series is a member of the sandy, mixed, mesic family of Alfic Udipsaments. They typically have very dark gray loamy fine sand A horizons 6 inches or less in thickness, and brown and yellowish brown loose fine sand C horizons containing thin brown horizontal bands of sandy loam B horizons below depths of about 3 feet.

Typifying Pedon: Chelsea loamy fine sand - wooded
(Colors are for moist soil unless otherwise stated.)

A11 -- 0-1" -- Very dark gray (10YR 3/1) loamy fine sand; grayish brown (10YR 5/2) dry; weak fine granular structure; very friable; much decomposed leaf litter; many fine roots; slightly acid; abrupt smooth boundary. (0 to 2 inches thick.)

A12 -- 1-4" -- Very dark grayish brown (10YR 3/2) loamy fine sand; grayish brown (10YR 5/2) dry; structureless, single grain; loose; medium to strongly acid; clear smooth boundary. (2 to 4 inches thick.)

AC -- 4-7" -- Dark grayish brown (10YR 4/2) and very dark grayish brown (10YR 3/2) fine sand, light brownish gray (10YR 6/2) dry; structureless, single grain; loose; strongly acid; gradual smooth boundary. (0 to 4 inches thick.)

C1 -- 7-15" -- Brown (10YR 4/3) fine sand, pale brown (10YR 6/3) dry; structureless, single grain moist, some very weak subangular blocky structure, dry; loose; strongly acid; gradual smooth boundary. (6 to 12 inches thick.)

C2 -- 15-36" -- Yellowish brown (10YR 5/4) fine sand; structureless, single grain; loose; some sand grains are dark brown; strongly acid; gradual smooth boundary. (12 to 24 inches thick.)

C&B -- 36-70" -- Light yellowish brown (10YR 6/4) fine sand; structureless, single grain; loose 1/2- to 2-inch thick brown (7.5YR 4/4) light sandy loam bands at 43, 49, 53, 59, and 67 inches; strongly acid.

Type Location: Linn County, Iowa; 280 feet north of the southwest corner of the SE1/4 sec. 27 and 60 feet east of fence on east side of Iowa Highway 13, T. 86 N., R. 6 W.

Range in Characteristics: Solum thickness ranges from 4 to many feet. Carbonates are lacking to depths of 60 inches or more. In most years, Chelsea soils are not dry in all subhorizons between 7 and 20 inches

CHELSEA SERIES (Cont.)

for 60 or more consecutive days nor in some subhorizon between these depths for 90 or more cumulative days. Soil temperature is estimated to range from 47° to 56° F. Mottles are lacking above 40 inches depth. Sand is dominantly fine, and material as coarse as gravel is lacking to depths of 40 inches or more. The soil typically ranges from strongly to medium acid in the most acid part. Thickness and color of the A1 or Ap horizons range considerably because this soil is very susceptible to wind erosion, and rodent activity is intense. Uneroded sites have very dark gray (10YR 3/1) and very dark grayish brown (10YR 3/2) A horizons up to 6 inches thick. Cultivated and eroded areas have Ap horizons that are dark grayish brown (10YR 4/2), dark brown (10YR 3/3) and brown (10YR 4/3). The A horizon is typically loamy fine sand, but some is fine sand. The upper part of the C horizon is brown (10YR 4/3), dark yellowish brown (10YR 4/4), or dark grayish brown (10YR 4/2). Texture is fine sand. The C2 horizon is light yellowish brown (10YR 6/4) or yellowish brown (10YR 5/4) fine sand. The soil has a B horizon of lamellae 1/4 to 2 inches thick that have 7.5YR or 10YR hue, value and chroma of 3 or 4, and texture of light sandy loam or loamy sand. Depth to the uppermost lamella commonly is about 3 feet and ranges from 27 to 48 inches. Total thickness of the lamallae in the part of the soil above 60 inches is less than 6 inches.

Competing Series and their Differentiae: These are the Bloomfield, Coloma, Graycalm, Hagener, Lamont, Levan, Oakville, Orwood, Oshtemo, Plainfield, Spinks, and Zimmerman series. Bloomfield soils have Bt horizons of finer texture. Coloma soils are higher in silt and clay and the sand fraction is coarser (See Remarks). Graycalm and Zimmerman soils have mean annual temperature of less than 49° F. Hagener soils have mollic epipedons, lack bands of B horizon, and are less acid. Lamont and Oshtemo soils have argillic horizons that are continuous in at least the upper 8 inches. Orwood soils have thicker A1 horizons and contain more silt and less sand. Oshtemo soils are dominantly of coarser sand, and the underlying sand and gravel are calcareous. Plainfield soils lack bands of B horizon above depths of 5 feet, and they contain less fine sand. Spinks soils have the bands of B horizon beginning at shallower depth and totaling more than 6 inches in thickness, and the soil is less acid.

Setting: Chelsea soils are on convex summits of interfluves, sideslopes, and crests of escarpments and are commonly along the eastern side of stream valleys. Slopes are mostly between 3 and 20 percent. Chelsea soils formed in eolian sand or sand from other sources reworked by wind. The sand is mostly fine. The climate is midcontinental type. Summers are hot and winters are cold. Mean annual temperature is about 49° F., and mean annual precipitation ranges from 30 to 34 inches.

Principal Associated Soils: In Iowa these are the Clinton, Fayette, and Lester soils, and the competing Lamont soils. The Clinton and Fayette soils are silty. Lester soils contain more clay, and have stones and pebbles in their sola.

CHELSEA SERIES (Cont.)

Drainage and Permeability: Drainage is excessive. Surface runoff is medium to rapid. Permeability is rapid.

Use and Vegetation: Many areas are in open woods used for grazing. Some is cropped to corn, oats, and hay. Native vegetation was oak-hickory forest.

Distribution and Extent: Central and eastern Iowa, southern Wisconsin, southeastern Minnesota, southern Michigan, and northern Indiana. Chelsea soils are moderately extensive.

Series Established: Tama County, Iowa, 1938.

Remarks: Chelsea soils were formerly classified as Gray-Brown Podzolic soils intergrading to Regosols. Differences between Colima soils and Chelsea soils are not clear at the present time.

Established Series
Rev. RWJ-EPW
12-6-67

CONOVER SERIES

The Conover series is a member of the fine-loamy, mixed, mesic family of Udollic Ochraqualfs. These soils typically have very dark grayish brown loam Ap horizons, lighter colored A2 horizons, yellowish brown mottled clay loam Bt horizons, and C horizons of calcareous loam till.

Typifying Pedon: Conover loam - cultivated
(Colors are for moist soil.)

Ap -- 0-8" -- Very dark grayish brown (10YR 3/2) loam; moderate fine granular structure; friable; high in organic matter; slightly acid; abrupt smooth boundary. (7 to 10 inches thick.)

A2 -- 8-11" -- Grayish brown (10YR 5/2) loam, few medium distinct yellowish brown (10YR 5/4) mottles; weak medium platy structure; friable; medium acid; clear wavy boundary. (3 to 6 inches thick.)

B21t -- 11-17" -- Yellowish brown (10YR 5/4) clay loam, common fine distinct light brownish gray (10YR 6/2) mottles; moderate medium subangular blocky structure; firm; thin discontinuous dark grayish brown (10YR 4/2 clay films; medium acid; gradual wavy boundary. (3 to 8 inches thick.)

B22t -- 17-34" -- Dark yellowish brown (10YR 4/4) clay loam, common medium distinct light brownish gray (10YR 6/2) mottles; moderate medium and coarse subangular blocky structure; firm; continuous dark grayish brown (10YR 4/2) clay films; medium acid; abrupt irregular boundary. (8 to 18 inches thick.)

Cg -- 34-60" -- Dark grayish brown (10YR 4/2) loam, common medium distinct yellowish brown (10YR 5/6) mottles; structureless, massive; firm; calcareous.

Type Location: Clinton County, Michigan, SE1/4NE1/4SE1/4 sec. 27, T. 5 N., R. 2 W.

Range in Characteristics: Solum thickness ranges from 24 to 40 inches, and is the same as the depth to carbonates. The solum ranges from medium to slightly acid, and reaction varies considerably within short distances and among bodies of the soil. Mean annual soil temperature is estimated to range from 47° to 52°F. Undisturbed areas have 2 to 5 inch thick A1 horizons that range from very dark gray (10YR 3/1) to black (10YR 2/1). The Ap horizon is very dark grayish brown (10YR 3/2), very dark gray (10YR 3/1), or very dark brown (10YR 2/2). The matrix of the A2 horizon ranges from grayish brown (10YR 5/2) to brown (10YR 5/3). In some pedons where the matrix has chroma of 2 or less

the A2 horizon lacks mottling. The A horizon is loam, silt loam, or sandy loam, the latter texture being on areas having overwash 6 to 15 inches thick. The matrix of the B horizon has hue of 10YR, value of 4 through 6, and chroma of 3 or 4. Mottles in the B horizon are light brownish gray (10YR 6/2), light gray (10YR 6/1), grayish brown (10YR 5/2), or gray (10YR 5/1). Coatings on ped faces in the Bt horizon have colors of 2 or lower chroma. The Bt horizon is silty clay loam, clay loam, or heavy loam. The C horizon is dark grayish brown (10YR 4/2), light brownish gray (10YR 6/2), grayish brown (10YR 5/2), or brown (10YR 5/3). It is loam, silt loam, or light clay loam.

Competing Series and Their Differentiae: Related or similar soils are in the Blount, Brookston, Capac, Celina, Crane, Crosby, Darrock, Havana, Locke, Metamora, Miami, Nokomis, Odell, Oran, Otterbein, Riceville, and Skyberg series. The Blount soils have lighter colored Ap horizons, heavy clay loam or light clay B horizons, and clay loam or silty clay loam C horizons. Brookston soils have thicker dark colored A horizons, and they are grayer in the upper part of the B horizon. The Capac soils have yellowish brown B1 horizons of high chroma (10YR 5/6-5/8) between base of the A horizon and the B2t horizon. Celina soils have lighter colored A horizons and lack mottles just below the Ap horizon. The Crane, Darrock, and Odell soils have mollic epipedons. Crosby soils have color value of 4 or 5 in the Ap horizon. Havana, Oran, Riceville, and Skyberg soils have C horizons of glacial till that is high in montmorillonite. The Locke soils have sandy clay loam Bt horizons, and sandy loam C horizons. Metamora soils have sandy loam texture in the upper part of the B horizon. Miami soils lack mottles in the A2 horizons and in the upper parts of the B2 horizons. Nokomis soils have thicker sola. See "Remarks" for comments on the Otterbein soils.

Setting: Conover soils are typically on Wisconsin till plains and low moraines. Slopes range from 0 to about 6 percent, and the dominant slopes are from 1 to 4 percent. The climate is continental. Mean annual precipitation is 29 to 37 inches, the mean annual temperature is about 48°F., and the mean summer temperature is about 70°F.

Principal Associated Soils: The competing Brookston, Celina, and Miami soils are in a drainage sequence with the Conover soils, and they are the most common associates. Carlisle soils are on associated nearly level to slightly concave adjoining slopes.

Drainage and Permeability: Somewhat poorly drained. Surface runoff is slow to medium; permeability is moderate to moderately slow.

Use and Vegetation: Largely under cultivation. Corn, beans, small grain, and legume-grass hay are the major crops. A small part is in forest. Native vegetation was hardwood forest.

Distribution and Extent: Southern Michigan and northern Indiana. The series is of large extent.

CONOVER SERIES (Cont.)

Series Established: Miami County, Ohio, 1916.

Remarks: The Conover soils were formerly classified in the Gray-Brown Podzolic great soil group. The available descriptions show substantial, if not complete, overlap in morphology of the Conover and Otterbein soils. Some differences in the original vegetation are postulated, but these cannot serve as differentiae between the two series.

National Cooperative Soil Survey
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APPROVED BY PRINCIPAL SOIL CORRELATOR
MIDWEST REGIONAL TSC

Established Series
Rev. ALZ-HPU-FWS
3/8/67

MIAMI SERIES

The Miami series is a member of the fine-loamy, mixed, mesic family of Typic Hapludalfs. Miami soils typically have brown silt loam or loam A horizons over yellowish-brown to dark brown clay loam B horizons. Solums are commonly 2 to 3 1/2 feet thick.

Typifying Pedon: Miami silt loam - forested area
(Colors are for moist conditions)

A1 -- 0-3" -- Very dark grayish-brown (10YR 3/2) silt loam; moderate medium and coarse granular structure; friable; slightly acid; clear wavy boundary. (1 to 3 inches thick.)

A21 -- 3-8" -- Brown (10YR 5/3) silt loam; moderate fine medium granular structure; friable; medium acid; clear smooth boundary. (0 to 7 inches thick.)

A22 -- 8-12" -- Yellowish-brown (10YR 5/4) silt loam; weak medium platy structure; friable; medium acid; clear wavy boundary. (0 to 5 inches thick.)

IIB21t -- 12-17" -- Dark brown (7.5YR 4/4) gritty silty clay loam; moderate medium subangular blocky structure; friable to firm; thin discontinuous pale brown (10YR 6/3) clay films on ped faces; medium acid; clear smooth boundary. (4 to 7 inches thick.)

IIB22t -- 17-25" -- Dark brown (10YR 4/3) clay loam; moderate to strong medium and coarse angular blocky structure; firm; thin pale brown (10YR 6/3) and dark brown (7.5YR 4/4) clay films on all ped faces and as lining in some voids; medium acid; clear wavy boundary. (4 to 10 inches thick.)

IIB23t -- 25-29" -- Dark brown (10YR 4/3) loam; weak coarse subangular blocky structure; friable; few thin discontinuous dark brown (7.5YR 4/4) clay films on ped faces and as lining in some voids; neutral; clear wavy boundary. (3 to 6 inches thick.)

IIB3 -- 29-36" -- Brown (10YR 5/3) loam; massive to weak coarse subangular blocky structure; friable; thin discontinuous dark brown (10YR 4/3) clay films; mildly alkaline (calcareous); clear irregular boundary. (5 to 9 inches thick.)

IIC -- 36-46"+-- Light yellowish-brown (10YR 6/4) loam till; massive: friable; moderately alkaline (calcareous).

MIAMI SERIES (Cont.)

Type Location: Rush County, Indiana, NW1/4 of NW1/4 of NE1/4, Sec. 12, T13N, R9E; 1 1/2 miles SW of Rushville to section line, then 500 feet west along N. section line and 25 feet south in wooded area.

Range in Characteristics: The mean annual soil temperature ranges from 47° to 55° F. Miami soils are not dry in all subhorizons between 7 and 20 inches in most years for 60 or more consecutive days nor in some subhorizon between these depths for 90 or more cumulative days in most years. Solum thickness ranges from 24 to 42 inches but it is dominantly 28 to 36 inches. Carbonates occur at a depth of less than 42 inches. B3 horizons are frequently calcareous except for clay films which may or may not be. The thickness of the loess capping is variable; ranging from 0 to 18 inches. The A1 horizon ranges in color from very dark grayish brown (10YR 3/2) to dark grayish brown (10YR 4/2) or very dark gray (10YR 3/1), in texture from loam and silt loam to sandy loam. The A2 horizons range in color from dark grayish brown (10YR 4/2), yellowish brown (10YR 5/4) to brown (10YR 5/3) or light yellowish brown (10YR 6/4), in texture from loam and silt loam to sandy loam, in structure from moderate medium or fine granular to weak or moderate thin to thick platy. In plowed areas the Ap horizon ranges in thickness from 6 to 10 inches and in color from dark grayish brown (10YR 4/2) to brown (10YR 5/3) or yellowish brown (10YR 5/4). A B1 horizon, 2 to 5 inches thick, may be present. The B2 horizons range in total thickness from about 16 to 30 inches. Colors of the B2 horizons range in hues of 10YR and 7.5YR with chromas ranging from 3 to 6 in values of 4 to 6 (in some areas the hues range to 5YR); clay films on ped faces and as lining of voids range from thin to thick and patchy or discontinuous to continuous; structure is moderate to strong medium to coarse in subangular or angular blocky peds; mostly firm in consistency but may be friable in the lower part; reaction ranges from medium to strongly acid and may grade to neutral in the lower part. Texture of the B2 horizons ranges from light clay loam to silty clay loam with the weighted clay content of the top 20 inches between 28 and 35 percent. Thin horizons up to 8 inches thick may range up to 40 percent clay. The B3 horizon may be absent in some pedons or described as a part of the B2 or C horizon. The C horizon consists of loam to light clay loam calcareous till.

Competing Series and Their Differentiae: Closely related or similar soils are in the Celina, Russell, Fox, Galena, Hillsdale, Alexandria, Cardington, Lewisburg, Corwin, Dodge, Montmorenci, Ockley, Thackery, Westville, Lapeer, McHenry, Woodbine, Wysox, Morley, Owosso and Strawn series. The Celina soils have low chroma mottles within the top 10 inches of the argillic horizon (Aquic Hapludalf). The Russell soils have smoother upper A and B horizons (fine-silty) (developed in thicker loess). The Fox soils have a lower solum which is higher in gravel content and have a thick beta horizon projecting into the loose calcareous gravel and sand C horizon. The Galena soils have a thicker and more acid solum. The Hillsdale soils have a thicker solum and a higher sand content. The Ockley and Thackery soils have thicker solums. The Lapeer soils have B2 horizons with less clay and

MIAMI SERIES (Cont.)

more sand. The McHenry soils have more silt and less sand in the upper part of the B horizons and more sand in the lower solum. The Wysox soils have more silt and less clay in the upper part of the B horizons and more sand in the lower part of the B horizon. The Woodbine soils have higher clay content in the lower solum. The Westville soils have thicker solums. Morely soils have more clay in the B horizon. The Strawn soils have thinner sola. Owosso soils have coarser textured upper B horizons. Alexandria, Lewisburg and Cardington soils are finer textured in the upper 20 inches of the argillic horizon. Corwin soils have mollic epipedons. Montmorence soils have thicker dark colored A1 horizons. Dodge soils have developed in silty acolian material more than 20 inches thick and glacial till.

Setting: Miami soils occur typically on nearly level to steep topography on moraines, drumlins and till plains. The regolith is calcareous loam to light clay loam till. Illite is the dominant clay mineral in the less than 2 micron particle size class of the glacial till. The climate is midcontinental type with hot summers and cold winters. The average daily maximum air temperature in July is as high as 88° F. and the average daily minimum temperature drops to about 22° F. in January. Mean annual precipitation is approximately 30 to 44 inches.

Principal Associated Soils: The moderately well drained Celina, somewhat poorly drained Crosby and Conover, and very poorly drained Brookston and Kokomo soils form a drainage sequence with the Miami soils and are the most closely associated series. The Parr and Octagon form a biosequence with the Miami series.

Drainage and Permeability: Well drained. Permeability is moderate. Runoff is medium on the milder slopes and rapid on the steeper slopes.

Use and Vegetation: A large proportion is under cultivation. The principal crops grown are corn, soybeans, small grain and legume grass mixture. A considerable proportion of the steeper slopes is in permanent pasture or forest.

Distribution and Extent: Indiana, southern Michigan, northeastern Illinois, southeastern Wisconsin, and western Ohio. The soil is extensive -- more than 100,000 acres.

Series Established: Montgomery County, Ohio, 1910.

Remarks: This series was formerly classified as Gray-Brown Podzolic. There are some soils which have been included with the Miami series in the past which belong in a fine rather than fine-loamy family and from this standpoint will be excluded from the series. This series is being updated by Indiana per instructions from A. R. Aandahl, May 5, 1966. Dr. Roy W. Simonson's letter of April 28, 1966 to Aandahl and Baur asked that the Midwest Region assume responsibility for bringing and keeping the standard description of the Miami series

MIAMI SERIES (Cont.)

up-to-date. The relationship of Kendallville to Miami is not clear at the present time. Miami is compared to all known closely competitive series. In the future this large family should be examined as a whole to develope criteria to differentiate all the series from each other and to test the need for this many series in a family. At that time all the series descriptions of soils in this family will be updated to point out the differentia.

National Cooperative Soil Survey

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Established Series
Rev. RWJ-EPW
8-66

SPINKS SERIES

The Spinks series is a member of the sandy, mixed, mesic family of Psammentic Hapludalfs. Typically, these soils have sand A horizons 15 or more inches thick and strong brown heavy loamy sand B horizons in bands that range from 1/4 to about 5 inches thick, and are separated at 5- to 10-inch intervals by lighter colored A2 layers of sand or loamy sand.

Typifying Pedon: Spinks loamy sand - cultivated
(Colors are for moist soil.)

Ap -- 0-7" -- Dark grayish brown (10YR 4/2) loamy sand; very weak medium granular structure; very friable; many roots; slightly acid; abrupt smooth boundary. (6 to 10 inches thick.)

A2 -- 7-23" -- Yellowish brown (10YR 5/4) sand; single grain; loose; many roots; slightly acid; abrupt wavy boundary. (10 to 30 inches thick.)

A2 & Bt -- 23-50" -- Pale brown (10YR 6/3) sand; structureless, single grain; loose; and strong brown (7.5YR 5/6) heavy loamy sand; structureless, massive; friable; slightly sticky; many fine roots in upper part, few in lower part; neutral. (20 to 40 inches thick.)

C -- 50-66" -- Pale brown (10YR 6/3) sand; single grain; loose; calcareous.

Type Location: Ionia County, Michigan. NE1/4SE1/4, Sec. 24, T. 6 N., R. 7 W.

Range in Characteristics: The solum usually ranges from medium acid to neutral, but the lower part is mildly alkaline in some pedons. Mean annual soil temperature is 47° to 54° F. The amount of gravel in the solum is typically very small, but some pedons contain up to 15 percent. The Ap horizon is dark grayish brown (10YR 4/2), brown (10YR 5/3), or grayish brown (10YR 5/2), and the texture is loamy sand, loamy fine sand, fine sand, or sand. The A2 horizon is yellowish brown (10YR 5/4) or brown (10YR 5/3). The depth to the first band of the Bt horizon ranges from 15 to about 36 inches. The thickness and sequence of the layers in the A2 and Bt horizon varies considerably in short horizontal distances. The thickness of the A2 layers or the distance between the Bt layers ranges from 5 to 10 inches. The thickness of the individual Bt layers ranges from 1/8 inch to about 5 inches, and they are commonly discontinuous. The cumulative thickness of the Bt layers is more than 6 inches. The color of the Bt layers ranges from strong brown (7.5YR 5/6) to dark yellowish brown (10YR 4/4) or brown (7.5YR 4/4). The individual bands or lamalla of the Bt horizon range from loamy sand to light sandy loam,

SPINKS SERIES (Cont.)

or heavy loamy fine sand, but the weighted average clay content of the combined bands falls within the loamy sand textural class and sandy family. The reaction of the C horizon ranges from moderately alkaline and calcareous to mildly alkaline.

Competing Series and their Differentiae: Related or similar soils are in the Arkport, Bloomfield, Boyer, Chelsea, Lamont, Montcalm, Oakville, Oshtemo, Plainfield, and Tyner series. Arkport soils have finer textured lamellae, and the control section contains enough clay for a coarse-loamy family. Bloomfield soils have thicker sola and thicker bands which are deeper in the sola. Boyer and Oshtemo soils have finer textured continuous Bt horizons that are generally more gravelly. Chelsea soils have medium to strongly acid sola, and the Bt layers begin deeper in the soil and are somewhat thinner and more widely spaced. Lamont soils have continuous Bt horizons, and the control section contains enough clay for a coarse-loamy family. Montcalm soils have bisequal sola that have weakly expressed spodic horizons in the upper sequum and weak tonguing of the A'2 horizon into the B't horizon in the lower sequum. Oakville soils lack Bt horizons within 60 inches of the surface. Plainfield soils are more acid and lack Bt horizons within depths of 60 inches.

Setting: Spinks soils are on moraines, till, plains, outwash plains, and beach ridges within lake plains of Wisconsin age. The dominant slopes are from 2 to 18 percent, and they range from 0 to 40 percent. The climate is continental. The average annual precipitation is 29 to 38 inches, the mean annual temperature is about 49° F., and the mean summer temperature is about 70° F.

Principal Associated Soils: These are the competing Boyer, Oakville, and Oshtemo soils, and the Dryden, Lapeer, Metea, Ottokee, and Owosso soils. The Dryden, Lapeer, Metea, Ottokee, and Owosso soils are on adjoining till plains or moraines, Boyer and Oshtemo soils on lake or outwash plains, and Oakville soils on either lake plains or moraines.

Drainage and Permeability: Well drained. Surface runoff ranges from slow to medium. Permeability is moderately rapid.

Use and Vegetation: Generally used for growing hay and pasture, and a small part is in corn, wheat, and soybeans. A small part is in orchards. A large part of the steeper areas is in forest or permanent pasture. The native vegetation was forests, dominantly of oaks and hickories.

Distribution and Extent: Southern Michigan and northwestern Ohio. The series is of moderate extent.

Series Established: McHenry County, Illinois, 1960.

SPINKS SERIES (Cont.)

Remarks: The Spinks series was formerly classified as Gray-Brown Podzolic soils. As mapped it has included some soils similar to the Chelsea soils.

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APPENDIX E

APPENDIX E

Form-SCS-232C-Soil Description 6-28-55

Soil type		File No.
Area	Date	Stop No.
Classification		
Location		
N. veg. (or crop)		Climate
Parent material		
Physiography		
Relief	Drainage	Salt or alkali
Elevation	Gr. water	Stoniness
Slope	Moisture	
Aspect	Root distrib.	
Erosion		
Permeability		
Additional notes		

Hori-zon	Depth	Color		Texture	Struc-ture	Consistence			Re-action	Bound-ary			
		Dry	Moist			Dry	Moist	Wet					

APPENDIX F

APPENDIX F

Blount loam

Location: NE 10, SE 40, NE 160, Section 36, Riley Township, Clinton County, Michigan.

Vegetation: Plowed alfalfa field.

Geology: Clay loam to silty clay loam till.

Tentative classification: Aeric Ochraqualf; fine-loamy, mixed, mesic.

Ap-0-8" - Dark grayish brown (10YR 4/2) loam to silt loam; weak medium to coarse subangular blocky and weak to moderate medium to coarse granular; firm to friable; pH 6.3; abrupt smooth boundary.

A-B-8-11" - Brown (7.5YR 5/4) to strong brown (7.5YR 5/6) with many distinct mottles of light brownish gray (10YR 6/2) to pale brown (10YR 6/3) silty clay loam to clay loam, with grayish brown (10YR 5/2) silty coatings on ped surfaces; moderate, medium, subangular blocky structure; hard; pH 6.0; clear smooth boundary.

B_{21}-11-19" - Strong brown (7.5YR 5/6) with common distinct mottles of dark grayish brown (10YR 4/2) and brown (10YR 5/3) fine clay loam to clay, with grayish brown (2.5Y 5/2) silty and clayey coatings on ped surfaces; weak, coarse prismatic to moderate, medium subangular and angular blocky structure; hard; pH 5.5; clear smooth boundary.

B_{22}-19-27" - Brown (10YR 5/3) to yellowish brown (10YR 5/4) with many distinct mottles of grayish brown (2.5Y 5/2) fine clay loam, with dark grayish brown (10YR 4/2) clayey

Blount loam (Cont.)

coatings on ped surfaces; weak, coarse prismatic to moderate, coarse subangular blocky and angular blocky structure; firm; pH 5.5; common brown to black iron and manganese concretions; clear smooth boundary.

B_3-27-32" - Yellowish brown (10YR 5/4) with many distinct mottles of grayish brown (2.5Y 5/2) and common distinct mottles of strong brown (7.5YR 5/6) clay loam, with grayish brown (2.5Y 5/2) clayey coatings on some ped surfaces; weak, coarse prismatic to weak, coarse subangular blocky structure; very firm; calcareous; few brown to black iron and manganese concretions; few calcans in lower part; gradual smooth boundary.

C-32-39" - Brown (10YR 5/3) to yellowish brown (10YR 5/4) clay loam with many light gray (10YR 6/1-7/1) calcans and grayish brown (2.5Y 5/2) organic coatings and root tracings; weak, coarse, prismatic to moderate, medium and coarse, subangular blocky structure; very firm; calcareous.

Remarks: This site occupied a gentle ridge with a slope gradient of 2% and a northern aspect. Relief was approximately 15 feet and drainage varied from somewhat poorly to moderately well. Roots were most common in upper solum but both roots and earthworms could be found to a depth of 42 inches, but mostly on ped faces in B & C horizons.

EPW
August 8, 1968

Note: The official classification of Blount is Aeric Ochraqualfs: fine, illitic, mesic. In contrast, this pedon analyzed fine-loamy and was described as mixed rather than illitic. The clay mineralogy was not determined. If the clay fraction were dominated by illite, this might explain why its swelling potential was lower than that of Conover or Miami.

Boyer sandy loam

Location: NE 10, SE 40, NE 160, Section 2, DeWitt Township, Clinton County, Michigan.

Vegetation: Idle.

Geology: Sandy glacial outwash.

Tentative classification: Typic Hapludalf: coarse-loamy, mixed, mesic.

Ap-0-10" - Dark brown (10YR 3/2) sandy loam; weak, medium subangular blocky breaking to weak, medium granular structure; friable; pH 5.5; abrupt smooth boundary.

A_2-10-15" - Yellowish-brown (10YR 5/6) gravelly loamy sand; weak coarse subangular blocky structure; friable; pH 5.7; abrupt smooth boundary.

B_1-15-19" - Brown to dark brown (7.5YR 4/4) gravelly sandy loam; weak to moderate medium subangular blocky structure; friable; pH 5.8; abrupt smooth boundary.

B_2-19-23" - Brown to dark brown (7.5YR 4/4) sandy loam with some dark brown (7.5YR 3/2) clay coatings on ped faces; weak to moderate, medium and coarse subangular blocky structure; firm; pH 6.5; abrupt wavy boundary.

B_3-23-28" - Dark brown (7.5YR 3/2) loamy sand; weak, coarse and medium subangular blocky structure; loose; pH 6.5; abrupt wavy boundary.

II C_1-28-33" - Yellowish brown (10YR 5/4) loamy sand; structureless - single grain; loose; pH 8.0; approximately 15% gravel to 1 inch in diameter; abrupt smooth boundary.

II C_2-33-42" - Yellowish brown (10YR 5/4) sand; structureless - single grain; loose; calcareous.

Boyer sandy loam (Cont.)

Remarks: This site was on a broad, gentle ridge just above a narrow alluvial area. The slope gradient was 1% and the aspect was south. The profile was well-drained with relief varying from 10-15 feet. Most roots were encountered above 30".

This profile varied from Boyer to something resembling a calcareous Spinks within the pit. At the north end of the pit a layer of organic material had accumulated at the B_3-C_1 contact.

WA, DD & EPW
August 7, 1968

Chelsea loamy sand

Location: Approximately 0.5 miles East of Chandler Road, 300 feet East of RR, NW 1/4, NE 1/4, Sec. 30, Bath Twp., Clinton County, Michigan.

Vegetation: Grass, weeds and small shrubs.

Geology: Sandy morraine.

Tentative classification: Alfic Udipsamment; sandy, mixed, mesic.

Ap-0-8" - Dark brown (10YR 3/3), with bands of black (10YR 2/1). loamy sand; weak fine granular structure; very friable; pH 5.7; abrupt smooth boundary.

B_1-8-21" - Strong brown (7.5YR 5/6) in upper part, grading into yellowish brown (10YR 5/8) in the lower part, loamy sand; weak fine granular structure; very friable; pH 6.0; clear smooth boundary.

A_{21}-21-29" - Yellowish brown (10YR 5.4) gravelly (?) sand; single grain structure; loose; pH 6.0; clear smooth boundary.

A_{22}-29-39" - Yellowish brown (10YR 5/6) sand; single grain structure; loose; pH 6.0; clear smooth boundary.

A_2 & B-39-49" - Strong brown (7.5YR 5/6), with bands of brown to dark brown (7.5YR 4/4), sand (bands - loamy sand); single grain structure (bands - weak fine subangular blocky structure); loose; pH 6.3; clear smooth boundary.

B & A-49-57" - Brown to dark brown (7.5YR 4/4), with bands of yellowish brown (10YR 5/4 & 10YR 5/6), loamy fine sand to fine sandy loam (bands - sand); weak medium subangular blocky structure (bands - single grain);

Chelsea loamy sand (Cont.)

very friable (bands - loose); pH 6.5; clear smooth boundary.

A & B-57-66+" - Yellowish brown (10YR 5/4), with bands of brown to dark brown (7.5YR 4/4), sand (bands - loamy fine sand); single grain structure (bands - massive structure); loose (bands - very friable, slightly plastic; pH 6.8.

Remarks: This site was on the crest of a ridge with a 5% slope and a western aspect. The profile was well drained and appeared to be somewhat low in moisture holding capacity. The relief varied from 30 to 40 feet. Roots were plentiful to the bottom of the A_2. Profile development varied around the pit from a pedon resembling Oshtemo ls to one resembling Oakville s, which seems characteristic of this taxonomic unit. Small chunks of free carbonate were observed in lower part of profile.

In the B & A horizon - 70% of horizon was B in the form of bands. In the A & B horizon - 65% of horizon was A. In the lower three horizons bands apparently cross horizon boundaries. When local calcareous zones are encountered matrix color becomes pale brown (10YR 6/3).

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August 7, 1968

Note: This profile is intermediate between Chelsea and Spinks. Problems attendent upon its placement are given in Appendix G.

Conover loam

Location: SE 10, SE 40, SW 160, Section 8, Ovid Township, Clinton County, Michigan.

Vegetation: Alfalfa.

Geology: Loam till.

Tentative classification: Aquic Hapludalf; fine-loamy, mixed, mesic.

Ap-0-8" - Brown to dark brown (10YR 4/3) loam; moderate medium subangular blocky and medium granular structure; friable; pH 6.5; abrupt smooth boundary.

B & A-8-12" - Strong brown (7.5YR 5/6) loam with common light brownish gray (10YR 6/2) clay coatings on ped faces; moderate medium and coarse subangular blocky structure; firm and slightly plastic; pH 6.8; clear smooth boundary.

B_{21t}-12-18" - Strong brown (7.5YR 5/6) with common medium distinct mottles of light brownish gray (10YR 6/2) clay loam, with brown to dark brown (7.5YR 4/4) clay skins on some ped faces; strong, medium subangular blocky structure; friable and slightly plastic; pH 7.0; clear, smooth boundary.

B_{22t}-18-26" - Yellowish brown (10YR 5/4) with many medium distinct mottles of grayish brown (10YR 5/2) and common medium faint mottles of yellowish brown (10YR 5/8) clay loam, with brown to dark brown (7.5YR 4/2) clay skins on some ped faces; medium, coarse subangular blocky structure; friable and slightly plastic; pH 6.2; clear smooth boundary.

Conover loam (Cont.)

B_{3t}-26-33" - Brown (10YR 5/3) with many medium distinct mottles of yellowish brown (10YR 5/8) and common medium faint mottles of grayish brown (10YR 5/2) loam, with brown to dark brown (7.5YR 4/2) clay skins on some ped faces; weak, coarse subangular blocky structure; friable and slightly plastic; clear smooth boundary.

C_1-33-40" - Mottled yellowish brown (10YR 5/8), light brownish gray (10YR 6/2) and yellowish brown (10YR 5.4) loam; weak coarse and very coarse subangular blocky structure; friable and slightly plastic; calcareous.

Remarks: This site was on a gentle side slope in an undulating area. The slope gradient was 4% and the aspect was northwest. This profile was somewhat poorly drained and relief was 10 to 15 feet. Most roots were encountered above 33 inches. A few manganese concretions were present in the B_{1t} while they were common in the B_{21t}, B_{22t} and B_{3t} horizons.

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Note: At the present time Conover is officially described as a member of the Udollic Ochraqualfs. This pedon was too high in chroma in the Ap, and too red in hue and too high in matrix chroma in the B&A and B_{21t} to fit the official series description.

"Miami" loam

Location: Approximately 0.6 miles South of Bennett Road on College Road, East of College Road and across from pump station #24, on MSU Farm, NW 10, NW 40, SW 160, Section 31, Ingham Twp., Ingham County, Michigan.

Vegetation: Alfalfa.

Geology: Loam till.

Tentative classification: Glossoboric Hapludalf; fine-loamy, mixed, mesic.

Ap-0-10" - Dark grayish brown (10YR 4/2) to very dark grayish brown (10YR 3/2) loam; weak medium subangular blocky and moderate to strong medium granular structure; friable; pH 7.0; abrupt smooth boundary.

A_2-10-14" - Brown (10YR 5/3), few medium distinct light brownish gray (10YR 6/2) and reddish brown (5YR 4/4) mottles, sandy loam; weak fine to medium subangular and weak fine granular structure; friable; pH 6.5; abrupt wavy boundary.

B_1-14-18" - Reddish brown (5YR 4/4), with common ped coatings of dark reddish brown (5YR 3/4) and interfingering of brown (10YR 5/3), loam; moderate medium to coarse subangular blocky structure breaking to moderate fine angular and subangular blocky structure; firm; pH 6.5; gradual wavy boundary.

B_{21}-18-26 - Brown (7.5YR 5/4), with many ped coatings of dark grayish brown (10YR 4/2) and few medium faint mottles of strong brown (7.5YR 5/6) and light brown (7.5YR 6/4),

"Miami" loam. (Cont.)

clay loam; moderate to strong angular and subangular blocky structure breaking to moderate fine angular blocky structure; firm; pH 6.5; diffuse smooth boundary.

B_{22}-26-34 - Yellowish brown (10YR 5/4), with few coatings of brown to dark brown (7.5YR 4/2), clay loam; weak coarse subangular blocky structure; firm; pH 7.5; clear smooth (?) boundary.

B_3-34-38 - Reddish brown (5YR 4/4), with many medium distinct mottles of brown (10YR 5/3), sandy loam; weak medium subangular blocky structure; friable; pH 8.0; abrupt smooth boundary.

C-38-48+ - Brown (10YR 5/3) sandy loam; massive in place breaking to medium coarse platy structure; friable; calcareous.

Remarks: This site was near the crest of a low ridge on a 3% slope with a northeastern aspect. The profile was well drained and relief varied from 15 to 20 feet. Most roots were found in the upper 30 inches but some were encountered at 36 inches or deeper. Earthworms were present throughout the profile, even into the C horizon and some fungal colonies were found in root channels into the B_3. This might have been caused by prolonged high soil moisture level during a wet summer.

This profile is not modal Miami as mapped in Ingham County but rather a pedon from "pink till" which is a taxonomic inclusion in the mapping unit. It comprises about 2-3% of the mapping unit.

Ped coatings in the B_1, B_{21}, and B_{22} seemed to be clay.

"Miami" loam. (Cont.)

Skeletans were noted on some 25% of vertical surfaces in B_1. Root channels were noted in the B_{22}. Several dolomite cobbles were found in the B_{22} horizon.

WA, DD, EPW & DA
August 6, 1968

APPENDIX G

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APPENDIX G

PROBLEMS IN SERIES PLACEMENT OF THE VERY SANDY SOIL

The pedon described and sampled in this study lies somewhere within that ill-defined region between Chelsea and Spinks. As a guide for those who wish to pursue the matter in detail, the following passages outline the differentiae between the series, and the ranges of these differentiae as given in the official series descriptions which are included in Appendix D.

CHELSEA SERIES (National Cooperative Soil Survey, 1968)

....

Range in Characteristics:

Solum thickness ranges from 4 to many feet. Carbonates are lacking to depths of 60 inches or more.... The soil typically ranges from strongly to medium acid in the most acid part.... The soil has a B horizon of lamella 1/4 to 2 inches thick that have 7.5YR or 10YR hue, value and chroma of 3 or 4, and texture of light sandy loam or loamy sand. Depth to the uppermost lamella is about 3 feet and ranges from 27 to 48 inches. Total thickness of the lamella in the upper part of the soil above 60 inches is less than 6 inches.

Competing Series and their Differentiae:

...Spinks soils have the bands of B horizon beginning at shallower depth and totaling more than 6 inches in thickness, and the soil is less acid.

SPINKS SERIES (National Cooperative Soil Survey, 1966)

....

Range in Characteristics:

The solum ranges from medium acid to neutral, but the lower part is mildly alkaline in some pedons.... The depth to the first band of the B_t horizon ranges from 15 to about 36 inches. The thickness of the sequence of layers in the A_2 and B_t horizon varies considerably in short horizontal distances. The thickness of the A_2 layers or the distance between the B_t layers ranges from 5 to 10 inches. The thickness of the individual B_t layers ranges from 1/8 inch to about 5 inches, and they are commonly discontinuous. The cumulative thickness of the B_t layers

SPINKS SERIES (Cont.)

> is more than 6 inches.
>
> Competing Series and their Differentiae:
>
> ...Chelsea soils have medium to strongly acid sola, and the B_t layers begin deeper in the soil and are somewhat thinner and more widely spaced.

These official series descriptions are current: the Spinks description was revised in 1966 and the Chelsea description in 1968. Therefore the differentiae used should be representative of those common in contemporary official series descriptions.

The differentiae are three:

1. Acidity
2. Depth to uppermost B horizon lamella (or B_t horizon band)
3. Total thickness of B horizon lamella (or cumulative thickness of B_t layers)

The pedon described and sampled is medium acid (pH 5.6-6.0) from 0 to 39 inches in depth, which would allow it within the range of both series; the depth to the first B horizon lamella (or B_t band) is greater than 39 inches (the horizon described as B_1 from 8-21 inches in depth increased in sand and decreased in clay from the horizon above), which would place it in Chelsea; while the total thickness of B horizon lamella (or cumulative thickness of B_t layers) is approximately 12 inches for that portion of the pedon above 60 inches in depth, which would place it in Spinks.

After an exercise such as this it is refreshing to contemplate Stebbing's discussion of the theory of classification (1950, p. 435):

> The basis of division (i.e. the differentiating characteristic) is often called by the Latin name "fundamentum divisionis". The principles regulating a logical division are usually summed up in the following rules:

> 1. There must be only one fundamentum divisionis at each step.
> 2. The division must be exhaustive.
> 3. The successive steps of the division (if there be more than one) must proceed by gradual stages.
>
> From Rule 1 there follows the corollary that the classes must be mutually exclusive. Violation of this rule results in the fallacy of cross-division, or overlapping classes. For example, if vehicles were divided into public-vehicles, private vehicles, motor-cars, and lorries there would be more than one basis of division, with the result that the classes would overlap.

It is difficult to understand how modern soil series descriptions continue to violate fundamental rules of logical classification in their differentiae between competing series. When the author of this dissertation attempts to place a pedon description within the defined limits of an official soil series, and to simultaneously keep it outside the range of all other official soil series, more often than not he is engulfed in rapid succession by the emotional states of futility, frustration, and anger.

APPENDIX H

APPENDIX H

Table 18. Physical analyses of five Tri-County soil series.

Series & horizon		Depth in inches	Particle size distribution %			Textural class	Swelling potential lbs./ft.^{2}	Bulk density g./cm.^{3}	Porosity		
			s	si	c				Large	Small	Total
Blount loam	Ap	0-8	46.5	37.7	15.8	l	300	1.58	7.5	36.2	43.7
	A-B	8-11	34.6	35.8	29.6	cl	1400	1.63	6.8	34.8	41.6
	B_{21}	11-19	31.9	39.5	28.6	cl	2100	1.67	4.8	35.4	40.2
	B_{22}	19-27	33.2	35.2	31.7	cl	2050	1.72	1.9	34.6	36.5
	B_3	27-32	32.3	39.4	28.3	cl	2400	1.82	2.5	31.2	33.8
	C	32-50+	28.3	42.1	29.6	cl	2200	1.91	3.8	31.0	34.8
Miami loam	Ap	0-9	50.0	39.9	10.1	l	200	1.46	4.5	37.5	42.1
	A_2	9-14	47.7	37.1	15.3	l	450	1.65	4.8	31.5	36.3
	B_1	14-18	44.3	31.7	24.0	l	1450	1.73	4.5	33.6	38.1
	B_{21}	18-26	41.9	29.5	28.6	cl	2350	1.62	3.0	37.8	40.8
	B_{22}	26-33	46.3	29.5	24.2	l	1600	1.66	4.0	36.9	40.9
	B_3	33-38	48.8	30.7	20.5	l	1250	1.66	2.7	35.8	38.5
	C	38-48+	51.9	30.5	17.6	l	700	1.80	3.7	31.0	34.7
Conover loam	Ap	0-8	41.7	43.2	15.1	l	300	1.60	6.9	33.9	40.8
	B&A	8-12	40.6	35.5	24.0	l	1100	1.67	7.2	31.6	38.8
	B_{21}	12-18	38.2	33.4	28.5	cl	2350	1.64	5.1	32.5	37.7
	B_{22}	18-26	39.5	33.3	27.2	cl	2200	1.60	5.9	33.4	39.3
	B_3	26-33	43.7	30.2	26.2	l	2100	1.64	4.2	31.9	36.0

Table 18. (Cont.)

Series & horizon		Depth in inches	Particle size distribution %			Textural class	Swelling potential lbs./$ft.^2$	Bulk density g./$cm.^3$	Porosity Large	Porosity Small	Porosity Total
			s	si	c						
	C	33-40	41.9	35.4	22.7	l	2500	1.84	4.5	30.4	34.9
Boyer	Ap	0-10	73.9	19.4	6.1	grsl	--	1.39	9.3	37.6	47.0
sandy	A_2	10-15	77.6	15.4	7.0	grls	--[1]	1.57	8.1	30.2	38.2
loam	B_1	15-20	80.5	10.8	8.7	grls	--	1.50	10.6	27.1	37.6
	B_2	20-23	80.8	8.3	11.0	grls	450	1.51	20.8	24.5	45.3
	B_3	23-28	86.3	4.0	9.7	ls	--	1.40	34.0	9.0	42.9
	IIC_1	28-33	94.2	5.9	--	fs	--	1.54	32.7	5.9	38.6
	IIC_2	33-42	96.2	2.0	1.9	s	--[2]	1.53	32.5	8.2	40.7
Chelsea	Ap	0-8	77.7	18.2	4.1	ls	--	1.48	5.9	40.2	46.1
loamy	B_1	8-21	87.8	11.8	.4	s	--[2]	1.49	6.7	36.5	43.2
sand	A_{21}	21-29	94.8	3.5	1.7	s	--	1.53	9.0	30.1	39.1
	A_{22}	29-39	97.5	.9	1.6	s	--[2]	1.51	6.1	32.8	38.8
	A_2&B	39-49	94.0	2.7	3.4	s	--	1.47	5.9	31.9	37.9
	B&A	49-57	92.4	2.4	5.2	s	50	1.54	3.6	35.4	39.0
	A&B	57-66	94.0	1.8	4.3	fs	--[1]	1.42	3.0	36.2	39.2

[1]Core did not swell.
[2]Soil would not compact.

Table 18. (Cont.)

Series & horizon		Moisture constants atmosphere - tension equivalent 0.06	0.10	0.33	15.0	%	Available moisture inches per inch	inches per horizon	inches per profile
Blount	A1	23.0	23.0	20.7	6.4	14.2	.22	1.80	
loam	A-B	21.3	20.1	19.4	9.8	9.6	.16	.47	
	B_{21}	21.2	20.7	19.0	12.1	6.9	.11	.92	
	B_{22}	20.1	19.6	18.3	12.1	6.2	.11	.85	
	B_3	17.2	17.0	15.9	11.0	4.9	.09	.45	
	C	16.3	16.0	15.1	11.0	4.1	.08	1.40	5.89 (5.81)[5]
Miami	Ap	25.9	22.4	18.9	5.2	13.7	.20	1.81	
loam	A_2	19.1	16.1	14.7	4.9	9.8	.16	.81	
	B_1	19.4	17.5	16.1	9.3	6.8	.12	.47	
	B_{21}	23.3	20.8	18.7	10.7	8.0	.13	1.04	
	B_{22}	22.3	19.5	16.4	8.8	7.6	.13	.88	
	B_3	21.6	18.7	15.6	8.2	7.4	.12	.61	
	C	17.2	15.4	13.5	6.8	6.7	.12	1.20	6.82 (6.82)[5]
Conover	Ap	21.2	21.2	19.0	6.4	12.6	.20	1.61	
loam	B&A	18.9	18.7	16.9	8.7	8.2	.14	.55	
	B_{21}	19.8	19.6	17.8	10.1	7.7	.13	.76	
	B_{22}	20.9	20.7	18.2	10.0	8.2	.13	1.04	

Table 18. (Cont.)

Series & horizon		Moisture constants atmosphere - tension equivalent 0.06	0.10	0.33	15.00	Available moisture %		inches per inch		inches per horizon			inches per profile
	B_3	19.5	19.3	17.6	9.6	8.0		.13		.92			
	C	16.6	16.6	15.2	9.1	6.1		.11		.78			5.66 (6.55)[5]
Boyer	Ap	27.2	14.9	10.9	3.9	6.9		.10		.96			
sandy	A_2	19.3	8.3	6.3	1.8	4.5	(17.5)[3]	.07	(.27)[3]	.35	(1.37)[3]		
loam	B_1	18.2	8.8	6.6	3.5	3.1	(14.7)	.05	(.22)	.23	(1.10)		
	B_2	16.2	15.4	13.4	4.0	9.4	(12.2)	.14	(.18)	.42	(0.55)		
	B_3	6.4	6.0	5.2	3.3	2.0	(3.1)	.03	(.04)	.14	(0.22)		
	IIC_1	3.8	3.4	2.5	.7	1.8	(3.1)	.03	(.05)	.14	(0.24)	(5.49)[4]	
	IIC_2	5.4	6.9	2.6	.5	2.1	(4.9)	.03	(.07)	.29	(0.67)		2.53 (2.73)[5]
Chelsea	Ap	27.2	13.7	7.8	2.6	5.2	(24.6)	.08	(.36)	.62	(2.91)		
loamy	B_1	24.5	10.1	6.2	1.7	4.6	(22.8)	.07	(.34)	.88	(4.42)		
sand	A_{21}	19.7	6.0	3.4	1.2	2.2	(18.5)	.03	(.28)	.27	(2.26)		
	A_{22}	21.8	5.3	2.8	1.1	1.7	(20.7)	.03	(.31)	.26	(3.13)		
	A_2&B	21.8	6.5	4.7	1.8	3.0	(20.0)	.04	(.29)	.43	(2.94)		
	B&A	20.0	9.5	6.0	2.5	3.6	(17.5)	.05	(.27)	.40	(2.16)	(17.58)[4]	
	A&B	25.5	14.1	5.5	2.0	3.5	(23.5)	.05	(.33)	.45	(3.00)		3.31 (2.42)[5]

[3]Available moisture values using .06 - 15 atmosphere-tension equivalent.
[4]Available moisture values (.06 - 15 atm.) expressed in inches per profile.
[5]Profile adjusted to 48 inches.